TEACHERS' BELIEFS AND VIEWS ABOUT STATISTICS EDUCATION

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The importance of beliefs as a factor affecting teaching and learning has long been established. In the field of statistics education, very little research has been conducted on the nature of teachers' beliefs, despite the likely impact these beliefs have on teachers' activities. This chapter first considers content-focused beliefs about statistics, its relationship with mathematics, and its place in the curriculum, before then addressing beliefs associated with teaching and learning statistics. Influence on beliefs and the impact that beliefs might have on teaching are considered, and suggestions for further research are proposed.

1 Introduction

The actions of teachers conducting statistics lessons are influenced by many factors. As they teach about measures of central tendency, for example, the approaches taken will be influenced by beliefs. These might include beliefs about whether students need to practice the procedure of computing the mean, whether students should see how statistics relates to real-world situations, whether technology might help students learn, and whether it is important that students are capable of learning how to make their own decisions about the most appropriate measure to use. The study of students' and teachers' beliefs in mathematics education has a long and extensive history; the story for statistics education is sparser and comparatively short, especially in the area of teachers' beliefs.

This chapter will use Philipp's (2007) definition of "beliefs" (2007), which derives from and attempts to clarify the variety of uses of the term in the literature. He defines beliefs as "psychologically held understandings, premises, or propositions about the world that are thought to be true" (p. 259). They are regarded as cognitive (and so are "known" in some sense); he also uses the metaphor of "lenses" through which we view the world (p. 258). Philipp contrasts beliefs with attitudes, which are more associated with emotions.

The importance of *students'* beliefs regarding statistics has been asserted for many years. Gal, Ginsburg, and Schau (1997, p. 38) highlight that, for students, beliefs matter because of their influence on (a) the teaching/learning process and (b) students' relationship with statistics beyond the classroom. The first point applies equally well to *teachers'* beliefs; the second, as highlighted by Estrada and Batanero (2008), will be affected by teachers' beliefs. This makes the study of teachers' beliefs in statistics education important.

1.1 Contextual Issues

There are important contextual issues to bear in mind when considering teachers' beliefs about statistics education. The first is the scope of "statistics". What is categorised as "statistics" in the school curriculum varies widely, from simple data representation at the primary level, through to beginning inference at the secondary level. Indeed, some statisticians may not believe that the data representation work in pre-secondary level curricula can truly be called statistics at all. Second, it must be noted that statistics, as a discipline, has only recently entered the curriculum in a substantial way. Although some countries have had statistics as part of the high school curriculum for 40 years (see, e.g., Parsian & Rejali, 2008) it is only in the last 20 or so years that it has received a major push (see, e.g., Australian Education Council, 1991; National Council of Teachers of Mathematics, 1989). In some countries the incorporation of statistics has come only in the past decade, especially for the primary/elementary (hereafter referred to as primary) curriculum, but even for the high school curriculum as well (e.g., Ainley & Monteiro, 2008; Newton, Dietiker, & Horvath, 2008; Opolot-Okurut, Mwanamoiza, & Opyene-Eluk, 2008; Wessels, 2008).

These two factors—the scope of statistics and the recency and place of statistics in the school curriculum—must be considered when discussing the beliefs of teachers involved in statistics education. These beliefs may be very different according to the age and stage of their students. Teachers also have a variety of prior life and academic experience. Some may have formally studied statistics at school and some may not; some may have taken a course in statistics as part of their academic teacher training and others may not. For those who have formally studied statistics, their views as a teacher may be closely aligned to their views as a student, especially if they have not been teaching for very long. If, on the other hand, some teachers' encounters with statistics have been within other disciplines or in everyday life situations then this experience may inform their belief framework. Finally, even if they have completed a statistics course in their pre-service training, the resulting beliefs may vary because of the relative emphases on theoretical statistics, applied statistics, and statistics education issues within the course.

1.2 Overview of this chapter

With this background in mind, there are a number of domains in which beliefs seem to be significant for teachers and the teaching of statistics in schools. In 1997, Gal et al. proposed some key areas for investigation, such as what teachers believe about statistics itself, the relationship between mathematics and statistics, the place of statistics in the curriculum, what statistics is important for students to learn, and how students learn statistics. The sections that follow examine these questions and some results and speculations will be presented. Shaughnessy (2007, p. 1001), however, points out that despite the years since Gal and colleagues proposed their questions, and despite a reiterated call for work in the area by Batanero, Garfield, Ottaviani, and Truran (2000), very little work has been done. The surveys by McLeod (1992), on students' beliefs in mathematics more generally, and by Thompson (1992) and Philipp (2007) on teachers' beliefs, give insights into possible issues, but statistics education is absent from their considerations. There were only a handful of papers on the topic presented at the ICMI/IASE conference in 2008 (Chick & Pierce, 2008; Eichler, 2008; Estrada & Batanero, 2008; Sedlmeier & Wassner, 2008), and what little has been done involves

case studies and/or small or convenience samples. Consequently, results about both teachers' beliefs in mathematics education and tertiary students' beliefs in statistics education may provide grounds for speculation about teachers and statistics education. Another section will consider influences on and impacts of beliefs, and belief change. The chapter concludes by suggesting some areas of critical attention.

2 Teachers' beliefs about statistics — discipline and curriculum issues

Central to a consideration of teachers' beliefs about statistics education are beliefs about statistics itself and its place in the curriculum. Are teachers' beliefs about statistics congruent with the views of statisticians and statistics educators? In asking this question, however, it is important to identify the views of the latter group. Statistics educators' perceptions about statistics education may suggest a set of "desirable beliefs" that they believe teachers ought to have.

A strong theme of the ICMI/IASE conference presentations was that teachers must be helped to see that statistics is not defined by a set of procedural computations but rather by investigative processes given expression in the range of societal activity (see, for example, the presentations in Panel 1, 2008). Pfannkuch (2008) expresses concern that when it comes, for example, to statistical graphs, schools emphasise construction techniques rather than the thinking needed for data-based decision-making. This highlights a possible mismatch between teachers' beliefs about statistics and how statistics educators view it.

Over a decade ago Cobb and Moore (1997, p. 801) also drew attention to features of the discipline of statistics and its relationship to mathematics:

> Statistics is a methodological discipline. It exists not for itself but rather to offer to other fields of study a coherent set of ideas and tools of dealing with data. The need for such a discipline arises from the omnipresence of variability. … Statistics requires a different kind of thinking, because data are not just numbers, they are numbers with context. (p. 801)

Wild and Pfannkuch (1999) highlighted ways in which statistical thinking is different from mathematical thinking, having investigative cycles, distinctive types of thinking, interrogative cycles, and characteristic dispositions. This provides a context for Pfannkuch's (2008) discussion of the implication of these beliefs for teaching.

> To be a teacher of statistics is to realise that one is not teaching a branch of mathematics but that one is teaching a discipline that has its own independent intellectual method. Students are now living in a society that demands evidence-based arguments and decisions. Therefore teachers play a crucial role in developing students' statistical thought processes. … First, statistical thinking or reasoning or literacy needs to be recognised as a key educational goal for all students. Second statistics needs to be valued as a distinct discipline. Finally, resources need to be put into more statistics education research to understand how to develop students' statistical concepts and thinking. (p. 5)

These views have been presented as a background to an examination of the beliefs about statistics held by teachers themselves, as opposed to statistics educators.

2.1 Beliefs about statistics

Teachers' beliefs about statistics itself will contribute to both their attitude towards teaching statistics and their practice. Such beliefs will depend on their own experiences of learning and using statistics. Primary school teachers will seldom have studied formal courses in statistics at the tertiary level, and so their beliefs may well reflect those of the secondary school students they once were. Secondary school mathematics/statistics teachers, in contrast, will likely have studied at least one tertiary statistics subject. With so few studies on teachers' actual beliefs, it is hypothesised that some information can be gained by consideration of students' beliefs, on the assumption that those beliefs leave a legacy when such students become teachers themselves.

For example, if a teacher has studied a tertiary course in statistics then their beliefs, as a teacher of statistics, may match one or more of the views held by tertiary students like the 20 Australian university students in Reid and Petocz's (2002) phenomenographic study of students' views of statistics. From interviews with these mathematics major students, taking a first or a third year course in statistics, six conceptions of statistics emerged. These were: Statistics is (1) individual numerical activities, (2) using individual statistical techniques, (3) a collection of statistical techniques, (4) the analysis and interpretation of data, (5) a way of understanding real life using different statistical models, and/or (6) an inclusive tool used to make sense of the world and develop personal meanings. Conception 1 suggests a belief that statistics is a particularly, and even exclusively, mathematical activity. Conception 6 recognises that statistics involves a way of thinking and sense-making, not merely calculations, reflecting Pfannkuch's (2008) views. The intervening four conceptions omit various aspects of the more sophisticated conceptions, so that, for example, Conception 4 omits reference to the real-life situations evident in Conception 5. Each of these conceptions or beliefs is likely to be a significant influence on a teacher's approach to teaching statistics.

In a study of primary teachers, Begg and Edwards (1999) collected data about views related to statistics from 22 practicing and 12 pre-service teachers. When asked about the usefulness of statistics several themes coinciding with Conceptions 5 and 6 emerged, including that it helps us make sense of our world; plan for the future; summarise information; and compare, organise, and predict;. However, these teachers also affirmed the belief that statistics can be "easily manipulated to support any view, be it wrong or right" (p.2), particularly as used by the media or politicians. Despite this perception, teachers generally disagreed with the statement "statistics are fairly worthless because people who have contrasting views on a certain issue can each use the same statistical finding to support their view" (p. 2).

Such a mixture of beliefs was found by Chick and Pierce (2008). Their data from 27 pre-service primary teachers employed a statistics beliefs survey using the SCAS instrument reported by Garfield (1996, cited in Gal et al., 1997). This group of teachers would not have studied a tertiary course in statistics. They did not hold strong beliefs about statistics or its value, although there was strong agreement with the item "To be

an intelligent consumer, it is necessary to know something about statistics". On the other hand, a majority agreed that "When buying a new car, asking a few friends about problems they have had with their cars is preferable to consulting an owner satisfaction survey in a consumer magazine", suggesting a belief that personal opinions are of more value than statistical reports.

2.2 Beliefs about the relationship between mathematics and statistics

In most countries, in both primary and secondary schools, the same teacher is responsible for teaching mathematics *and* statistics. Teachers' and pre-service teachers' beliefs about the relationship between mathematics and statistics at the school level vary. Statistics typically is included under the umbrella of the mathematics curriculum and, in fact, anecdotal evidence suggests that primary teachers, for example, may not think of themselves as teaching 'statistics' but rather some applied number work. Begg and Edwards (1999) found that most of the practising and pre-service primary teachers, they surveyed, believed that statistics was part of mathematics but thought that a good understanding of mathematics was not actually needed in order to grasp basic statistical concepts. Many participants asserted that "statistics gives students who might have had a 'bad' experience with maths another chance" (p. 2). On the other hand, the pre-service primary teachers surveyed by Chick and Pierce (2008) were split in their responses to the statement "You must be good at mathematics to understand basic statistical concepts" among those who disagreed (41%), were neutral (22%), or agreed (37%).

Although the teachers in Begg and Edward's (1999) study recognised the cross-curricula nature of statistics, they taught it as part of mathematics. Those who valued statistics did so because, in their view, statistics gives meaning to mathematics and they believe that their students find statistics motivating and fun (with an implicit suggestion that mathematics is not). The majority of practicing teachers in Begg and Edwards' study saw teaching statistics as the same as teaching mathematics, while those in the pre-service group were not as sure of this, but still viewed them similarly: "it's part of maths; we know it's a maths thing" (p. 5).

Finally, little work has been done on whether teachers hold different beliefs about how mathematical and statistical activities are conducted. Starting with common beliefs about mathematics, Gal and Ginsberg (1994) suggested that it may be informative to consider Schoenfeld's list (1992, p. 359) of the typical student beliefs about the nature of mathematics and mathematical activity. Schoenfeld suggests that students had come to believe that, for example, mathematics problems have one and only one right answer and one method of solution (the one just demonstrated by the teacher), that mathematics is a solitary activity, and that problems can be solved in five minutes or less. Whether or not *teachers* believe this about mathematics is another question; more salient for this chapter is whether these beliefs are held by teachers or students for *statistics*. There is potential for differences here; certainly the lesson plans produced by pre-service primary teachers in the study of Chick and Pierce (2008) seemed to reflect a belief that group work—rather than working alone—is appropriate for learning about statistics.

2.3 Beliefs about the place of statistics in the curriculum

Statistical literacy and the analysis of quantitative data are required both across school disciplines and outside the classroom (Watson, 2006). Whereas statistics may be taught as part of mathematics, statistical literacy is needed, for example, to understand articles in the media, record or interpret results in science, monitor performance of sporting teams, or to quantify and represent the extent of some social problem. When considering the place of statistics within the curriculum Begg and Edward's (1999) respondents all thought that studying statistics was important for primary school children but only a quarter thought it was "really important" or "one of the most important areas" (p. 6). Of Chick and Pierce's (2008) pre-service primary teachers 15% agreed that primary school students probably spend enough time on statistics/data with a further 70% neutral. Sedlmeier and Wassner (2008) surveyed 40 secondary mathematics teachers who also taught statistics in German high schools (Gymnasium). When asked about the importance of statistics in daily life as compared with other areas of mathematics education, just over 50% said it was of higher importance (and only 10% said statistics was less important than other topics); however, when asked if statistics should be "given more hours per week even if this meant other mathematics topics got less" fewer than 20% agreed.

Across this limited number of studies, the majority of teachers surveyed believed that understanding statistics is important for everyday life. However it is not known where they believe this teaching is best placed: under the umbrella of mathematics or in the context of other disciplines. Statistics seems to be "accepted" as part of mathematics, yet this may sit uneasily with the idea, discussed earlier, that it is separate. In addition we know nothing of the views of teachers, at the secondary level, who specialise in teaching disciplines other than mathematics and statistics. Do they believe that statistics is integral to the part of the curriculum that is their focus, or do they see it as the sole responsibility of the mathematics teachers?

3 Teachers' beliefs about the teaching and learning of statistics

3.1 Beliefs about what statistics is important for students to learn

Increasingly it is taken as given that to be an informed citizen in today's world one needs a basic understanding of statistics. This view, sometimes externally imposed by curriculum or policy, impacts on individual teacher's beliefs about what statistics is important for students to learn. Believing that "to be an intelligent consumer it is necessary to know something about statistics"—a view held by most respondents in the studies of Begg and Edwards (1999) and Chick and Pierce (2008)—reflects this common perception. It is reasonable to expect that these beliefs will influence what statistics teachers believe students should learn.

Perception of the increasing importance of statistical literacy for everyday life has certainly had an influence on beliefs about what should be taught, but other perceptions have influence too. Aksu (1990, cited in Gattuso, 2006), for example, notes that teachers saw "descriptive statistics as easy and not very interesting" and consequently relegated statistics to the end of the school year, if there was time available. In the Begg and Edwards study (1999) teachers expressed a belief that statistics has utilitarian value for functioning in all areas of life. Virtually all these teachers mentioned teaching

graphing and data collection. These are essentially procedural skills. Beyond this, teachers indicated that they believed graphs were valuable for communication but far fewer referred to graphs as data exploration tools. Watson (2001) profiled 43 teachers (primary $n = 15$, and secondary $n = 28$) with respect to teaching the new curriculum topics of chance and data, and noted a typical response from a primary teacher indicating the pressure they feel to prepare their students to take civic and social responsibility: "Children live in a world where data is [sic] flowing so fast that they must be able to comprehend what is going on". The secondary teachers believed it was important to teach such topics as graph interpretation/construction, central measures, spread of data, practical applications, probability and how it is used in society as well as arrays/trees, diagrams, etc. Primary teachers were more likely to suggest student surveys, focussing on interests and hobbies.

These few examples show a trend towards an increased emphasis on statistical thinking and literacy, although it is difficult to tell to what extent deep statistical reasoning, of the kind called for by Pfannkuch (2008), is taking place.

3.2 Beliefs about teaching and learning statistics

Beliefs about teaching and learning statistics will naturally be linked to the age and stage of the students involved and to teachers' views about teaching in general and teaching mathematics in particular. Learning in context, with discussion as an important class activity, is believed by statistics education researchers to be key to teaching statistics. This view, however, is not held by all teachers. Eichler (2007) investigated German secondary school teacher's beliefs about teaching statistics for senior students. As part of his study he developed case studies of 13 upper secondary mathematics teachers, focusing in part on their "individual curricula", by which he means what teachers "planned" to do. Such individual curricula give insights into teachers' beliefs. Following careful qualitative analysis of the data Eichler described four categories that reflected the teachers' beliefs about teaching stochastics: traditionalists, application preparers, everyday life preparers, and structuralists. *Traditionalists* emphasised mathematical theory and were less concerned about applications. They saw descriptive statistics as superfluous and believed it is important (perhaps even sufficient) for students to gain algorithmic skills. *Application preparers* also taught the mathematical theory but with the goal of students using this theory to solve problems in real-world contexts. These teachers believed students should attain algorithmic skills but in context and with knowledge of the strengths and limitations for describing the real world. *Everyday life preparers* taught through applications. They believed that this approach should result in an ability to cope with real stochastic problems and the ability to criticise and discuss the situation. Finally, *structuralists* examined applications but not to promote interplay between theory and applications nor prepare students for dealing with contextual problems. They believed applications are a starting point for exemplifying mathematical theory, leading to understanding of abstract systems.

Traditionalists and structuralists appear to hold views about statistics and its teaching at odds with Shaughnessy (2007, p. 1002), who emphasised context and the view that statistics is fundamentally different from mathematics. In terms of the list of

conceptions found by Reid and Petocz (2002) such teachers might hold Conceptions 1, 2, or 3 but are less likely to hold Conceptions 4, 5 or 6.

There may also be a mismatch between what teachers say they believe about teaching statistics and what they are prepared to put into practice. The mathematics teachers in Sedlmeier and Wassner's (2008) study believed that their senior secondary students found the inferential statistics being taught harder to understand than other mathematical topics taught in school. In a survey these teachers rated the following strategies highly for good instruction in statistics: making connections with other (non-mathematical), highlighting the relationship between content taught and daily life issues, discussing different problem solutions (including students' suggestions), and addressing students' interests. Such responses would tend to suggest that these teachers would belong to Eichler's (2007) "everyday life preparers" and "application preparers" categories. Despite indicating in the survey that they thought these strategies were important for statistics instruction, however, Sedlmeier (2008) claimed many teachers were neither keen to base their instruction on students' own data collection nor put more emphasis on students' interests. This was particularly true of older teachers; younger teachers, in contrast, believed more strongly in making connections to daily life, using relevant examples, and conducting real experiments.

4 Influences on and impacts of teachers' beliefs

4.1 Influences on beliefs about teaching statistics

A variety of factors are likely to influence teachers' beliefs about statistics education, although this, too, has been studied very little. Begg and Edwards (1999) found that teachers' beliefs were related to their prior experiences, with evidence that their beliefs about statistics as process-oriented reflected their own learning experiences. This suggests likely differences between primary and secondary teachers based on the number and depth of statistics courses experienced, as well as on the nature of those courses. More specifically, Carvalho (2008) suggests that teachers may find it hard to implement interactive, experiential, practical statistics learning experiences if they have never themselves experienced this style of teaching.

Beliefs about teaching statistics are also likely to be influenced by beliefs about statistics itself (including its relationship to mathematics) and about teaching more generally. For example, if teachers teach mathematics in a decontextualised way then they may use a similar approach in statistics, perhaps practicing procedures first before giving "application" examples with a weak context as window-dressing. Beliefs about teaching statistics may also be influenced by the extent to which teachers see the value and use of statistics, such as having real-world relevance. Similarly, mathematics teachers who do not strongly value group work, but who feel pressure to conduct it, may believe that statistics lessons afford this opportunity more so than other topics.

4.2 Impacts of beliefs

The connection between beliefs and actions is one of the key reasons for investigating beliefs, and has been part of the mathematics education literature. Chick and Pierce

(2008) examined the lesson plans of 27 pre-service primary teachers asked to incorporate statistical concepts from a given data set in their lessons. They found that the most common features of the lessons were the intention to encourage class discussions, and to have students share their findings or graphs in small groups, but with little emphasis on teaching students to engage with and interpret the data given. Despite their limited content and pedagogical content knowledge, which hampered their ability to convey statistical ideas, these pre-service teachers' belief in "group work" and "class discussion" appears to recognise that an interactive approach would best serve the purpose of engaging the students with statistical ideas.

The case studies of Eichler (2008) also provide a rare direct examination of the impacts of beliefs. He explored connections between teachers' beliefs, as expressed by their intentions for their curriculum, and their enacted curriculum in the classroom. He found strong links between the two. One teacher espoused the importance of real statistical problems and actually used them to develop statistical methods in class. Another emphasised the importance of establishing a theoretical foundation for statistics and used more routine tasks and traditional methods. Eichler also explored the possibility of connections between the teachers' beliefs and actions, and the beliefs about statistics expressed by some of their students after the completion of their statistics course. In one case a teacher allowed students to make up their own problems (in itself, probably reflecting a teacher belief) or supplied examples in real contexts but with unrealistic data, and this seemed to result in the students believing that statistics had no relevance in their lives.

Implicit in Eichler's study, and in the discussion of the impact of beliefs, is the causality connection. This has not, however, been explored in detail to measure the magnitude of effects if they really exist. It is not yet known if a particular belief about statistics education is likely to result in a particular outcome, or whether given outcomes and actions can be attributed to certain beliefs.

4.3 Effecting changes in beliefs

Given the potential for mismatches between teachers' beliefs and those of statistics educators, as discussed earlier, further work is needed on how to modify the beliefs of those who, for example, perceive statistics only as algorithms to be learned devoid of context, and what professional development experiences offer the greatest potential for change. Despite the lack of research in this area there is, at least, some evidence of positive change as a result of professional development. Frierson, Friel, Brerenson, Bright, and Tremblay (1993) asked teachers, participating in a professional development program, about the statistics concepts that they believed were appropriate for Grade 3. Prior to the professional development program the teachers nominated "isolated content" such as graphing, probability, or organising data, but following the program their views had shifted and they were advocating more "conceptual ideas such as formulating questions, or interpreting data" (p. 42).

5 Discussion and Conclusions

5.1 Researching beliefs

In 1994 Gal and Ginsberg highlighted the importance of researching the role of beliefs and attitudes in statistics education. They discussed some of the typical tests used at that time to consider attitudes, pointed out a range of problems, and suggested the need for open questions and interviews. This call for more qualitative approaches has not been heeded to any great degree, apart from the relatively small body of work discussed here. There is a need to design specific instruments to examine the beliefs of teachers. The SCAS (STARC Chance Abbreviated Scale) instrument, introduced by Garfield (1996; cited in Gal et al., 1997) uses a five-point Likert scale to explore understanding, attitudes, and beliefs about statistics, including its relevance to functioning in society. While the SCAS instrument was of some value in the study of Chick and Pierce (2008), future studies of teachers might provide richer data if the items were framed to more tightly target statistics teaching. As it stands, the SCAS instrument deals with personal beliefs about statistics and its value, but does not examine how teachers perceive the value of statistics as part of the curriculum or as something important for students and future participants in society to learn.

5.2 An agenda for future research

Statistics has been introduced into the primary and secondary school curricula of many countries. It appears that statistics, when preent in the curriculum, is universally included within mathematics. The cited studies suggest teachers believe that understanding statistics is important for educated citizens. There is, however, considerable diversity in the beliefs held by these teachers who are expected to teach statistics. The source of this variability includes the teachers' background experience in learning or using statistics, and their consequent belief about what it means to do and understand statistics. Following from this can be seen a diversity of beliefs about what aspects of statistics should be taught in schools and how this should be taught. This latter belief is also influenced by the teachers' general beliefs about teaching and learning, and particular views on teaching mathematics.

At stated throughout this chapter, little research has been done on teachers' beliefs and how they impact on the teaching and learning of statistics. The questions of Gal et al. (1997) have been answered only incompletely and require further research. In addition to the need for larger, more systematic studies to enhance the small-scale studies of the past, the following questions should be investigated further.

- What do teachers believe about statistics itself? How is this influenced by background?
- What do teachers believe about the relationship between mathematics and statistics?
- What do teachers believe are the key features of statistical thinking that they should develop in their students?
- What do teachers believe are barriers and enablers for teaching statistical thinking, not just procedural routines?
- What impact do beliefs have on actual classroom practices?
- What professional development activities lead to change in beliefs?

- How does the local situation (culture, history, curriculum) affect teachers' beliefs?
- What are the interactions amongst beliefs, technology use, and statistics learning?
- What beliefs about statistics education are held by non-mathematics/statistics teachers whose subject areas require statistical literacy?

The answers to these questions would help us better understand the factors that influence classroom practice in statistics education.

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