Earlier mathematics achievement and success in university studies

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This study explores connections between earlier mathematics achievement in high school, success in university statistics and quantitative methods courses and experienced difficulties in quantitative methods courses. Earlier achievement in mathematics correlated with statistics grade in university studies, but not with quantitative methods course grade. Earlier achievement in mathematics was related to the experience of one's own ability in mathematical subjects and quantitative methods, but it was not related to other experienced difficulties. Ability in mathematical subjects and quantitative methods was further connected to other difficulties experienced in quantitative methods. The experienced difficulties and achievement in university courses were not related.

Many university social science students consider their quantitative methods and statistics courses problematic and more difficult than their other courses (e.g. Filinson & Niklas, 1992; Forte, 1995; Garfield & Ahlgren, 1988; Hauff & Fogarty, 1996; Lehtinen & Rui, 1995; Murtonen & Lehtinen, in press; Onwuegbuzie & Daley, 1998; Pretorius & Norman, 1992; Rosenthal & Wilson, 1992; Thompson, 1994; Townsend et al, 1998; Zeidner, 1991). The experience of difficulty in methods courses may be connected to students' previous experiences and achievement in similar domains, e.g. mathematics. The goal of this paper is to analyse how earlier achievement in high school mathematics is related to difficulties experienced in quantitative methods learning and to what kinds of difficulties, as well as whether the experienced difficulties are connected to achievement in university courses. No previous studies have been done on difficulties

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experienced in quantitative methods studies in relation to earlier mathematics achievement and achievement in university, but there are studies concerning statistics anxiety, prior knowledge and achievement.

Statistics anxiety has been noted as a serious problem in social sciences' quantitative methods and statistics courses (e.g. Birenbaum & Eylath, 1994; Forte, 1995; Pretorius & Norman, 1992; Townsend et al, 1998; Zeidner, 1991). The studies on statistics anxiety have their roots in mathematics anxiety and beliefs studies. Anxiety toward mathematics has been found to begin at an early age, as over 60 % of 9- to 11-year-old pupils reported some degree of mathematical anxiety in Newstead's study (1998). Schoenfeld (1989) has explored the relation between mathematical beliefs and achievement. He concludes that the students' sense of their own mathematical ability, their expected mathematical performance and their overall academic performance all correlate strongly with each other. Mathematics anxiety in university students has also been studied. In the studies by Betz (1978) and Clute (1984), high mathematics anxiety was found to be related to poor achievement in mathematics courses. On the contrary, Resnick et al (1982) found that mathematics anxiety did not predict mathematics performance in a large sample of university students. In the case of university students the connection between mathematics anxiety and performance in mathematics is thus not clear.

The connection from mathematics to statistics has inspired some researchers to investigate the impact of mathematics anxiety on statistics learning in university students and to develop specific statistics anxiety measures. According to Zeidner's results (1991), statistics anxiety paralleled some known features of mathematics anxiety in the same behavioural science student population. Zeidner's study revealed that negative prior experiences with mathematics, poor prior achievement in mathematics and a low sense of mathematical self-efficacy are meaningful antecedent correlates of statistics anxiety. Birenbaum and Eylath (1994) explored different correlates of statistics anxiety among students of educational sciences and found that mathematics and statistics anxiety were related, both being connected to a low earlier high school mathematics grade. Earlier mathematics achievement thus seems to be related to statistics anxiety.

Birenbaum and Eylath (1994) have studied the impact of experience with statistics on statistics anxiety. They concluded that the previous experience with statistics courses, i.e. whether or not the student had previously taken courses in statistics, did not affect statistics anxiety. Thus, although previous experiences in high school mathematics are related to statistics anxiety, the experience at university does not reduce or increase anxiety.

When focusing on achievement in university courses, Townsend et al. (1998) found that university psychology students' mathematics background did become a significant predictor of overall achievement in the statistics course. The students who had taken more mathematics courses had higher statistics grades than the students with fewer mathematics courses. Although the number of courses taken was connected to success, earlier achievement seems not to be so clearly related to success at university. Birenbaum and Eylath (1994) found that the earlier high school mathematics grade was only weakly connected to the statistics course grade at university.

Pretorius and Norman (1992) compared psychology students on a research methodology course in terms of passing or failing. They found that the most anxious students did not pass the courses. On the contrary, Townsend et al (1998) found that self-concept and anxiety were not strongly associated with achievement. Also in Rosenthal's and Wilson's study (1992) on a social work master students' research course, it was found that confidence in undertaking the research course was not related to performance. In the study of Birenbaum and Eylath (1994), neither statistics nor mathematics anxiety was connected to the statistics-related course grade.

In summary, previous research suggests that earlier achievement in mathematics correlates with statistics anxiety and also weakly with achievement in university statistics and methodology courses, but that there is not necessarily any relationship between anxiety and achievement, at least when achievement is looked at as a grade. Figure 1 shows the possible connections.

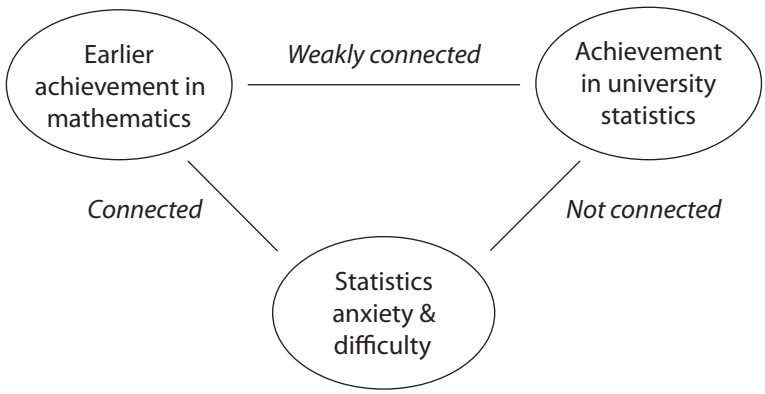

Figure 1. *Assumed relationship magnitudes between earlier achievement in mathematics, statistics anxiety and difficulty, and achievement in university statistics.*

University students experiencing difficulties in their quantitative methods courses might, however, not only have problems that are related to statistics anxiety. The questions in statistics anxiety questionnaires usually concern emotional states, such as feeling anxious about using statistical tables, reading a formula or signing up for a statistics course (e.g. Zeidner, 1991). In this study we were interested in studying also other kinds of problems that the students may have, and whether they are related to achievement.

In the study of Murtonen and Lehtinen (2003), students were asked to give descriptions of their difficulties during a quantitative methods course. They described different kinds of problems concerning 1) method of teaching and lack of time, 2) linking theory with practice, 3) establishing an integrated picture of the parts of scientific research in order to really understand it, 4) negative attitude toward these studies, and 5) unfamiliarity and difficulty of concepts and content. None of these categories, except category 4, fit under the label "anxiety", although they may well be connected to it. These problems are more cognitive and may have their origin in instruction. In this paper, we investigate the different kinds of experienced difficulties described above in relation to earlier achievement in mathematics and study success at university.

Method

The sample consisted of 74 social science and education students in Finland. The students were from three departments: education (29), psychology (26) and sociology (19). All the students present at the data collections filled out the questionnaire. The students were approximately third year students and doing a master's degree. (In Finland, the students are committed from the outset of their studies to doing a master's degree.) In our previous research (Murtonen & Lehtinen, in press; Murtonen, 2001), we have found that social science students and education students do not differ from each other in their experienced difficulties and that is why we study these groups here as one group (and as shown later, there were no differences between the groups in this study either). All students had enrolled in some introductory courses in methodology in previous terms. The sociology students were enrolled in a qualitative methods course, while the education and psychology students were enrolled in quantitative methods courses (each department taught a separate course). Of the subjects, 56 (77 %) were women and 17 (23 %) were men.

The instrument was a questionnaire concerning Difficulties in Quantitative Methods (DQM). The questionnaire was developed on the basis of the results of Murtonen and Lehtinen (2003), and comprised 17 statements

concerning experienced difficulties in quantitative methods learning and courses. The statements covered instruction in courses, interest in quantitative methods, superficiality in courses, students' ability in mathematical subjects and lack of connection between parts in the methodology domain (see Table 1). Students responded to each item on a Likert scale ranging from *strongly disagree* (1) to *strongly agree* (5). The statements were not restricted to a specific course but were more general in nature.

Students were asked to give their high school mathematics grade in the questionnaire. University statistics and quantitative methods course grades were taken from the university's student registry, and standardised within the major subject groups. Data collection took place in the beginning of the methods courses. The teacher was responsible for both distributing the questionnaires to the students and collecting them. Students filled in the questionnaires at the beginning of a lecture. The questionnaire began with a short note for the students about the research project and about the importance of their answers for the study.

Results

A principal component analysis was run with the 17 questions of the DQM instrument. The loadings are shown in Table 1. This solution was satisfactory both theoretically and statistically, explaining 65 % of the total variance.

Sum variables were constructed on the basis of the components for further analysis. The first sum variable (PC1) was named Instruction ($M = 3.36$, $SD = .81$), because most of the questions concerned teachers and instruction. The second (PC2) was named Interest ($M = 2.64$, $SD = .83$), as it dealt with attitudes toward learning and quantitative methods courses. The third component (PC3) was called Superficiality ($M = 3.46$, $SD = .79$), since the items were about the time spent on and the depth of learning in courses. The fourth component (PC4) was named Ability ($M = 2.92$, $SD = 1.00$), which refers to the students' own conceptions of themselves as learners of mathematical and technical subjects, as well as the amount of effort this kind of course requires of them. The last component (PC5) was named Unconnection ($M = 3.45$, $SD = .81$), because the items were about the degree to which different parts of the research methodology were felt to be unconnected.

On the basis of the means of the sum variables, the students saw issues related to Instruction, Superficiality and Unconnection as the most problematic ones, while they reported fewer problems with their Ability and Interest. The mean of Ability was, however, almost 3, which indicates that the students had problems with the feeling of their own ability.

Table 1. *Principal component loadings (a 5-component Varimax solution) of items in DQM inventory*

Variable	Principal component				
	PC1	PC2	PC3	PC4	PC5
1. I'm not interested in quantitative methods		.79			
2. There is not enough real world application in courses			.72		
3. I'm not good at mathematics and that's why I'm not good at methodology				.79	
4. Computers are difficult to use when doing analyses				.79	
5. The teaching is too superficial			.79		
6. The teaching is too hasty: there is no time in the lecture to really get familiar with the subject			.78		
7. Examples used in courses are not interesting		.54			-.54
8. Methodological skills are easy to forget, because you don't need them daily					.61
9. The data used in courses are not interesting because they do not feel real/my own		.67			
10. It's hard to see links between different parts of research methodology	.49				.62
11. Methodological concepts are hard to understand	.79				
12. Too many new concepts are introduced too fast during courses	.83				
13. Teachers use too difficult language and do not explain things	.72				
14. Teachers do not see and understand students' problems	.61				
15. I have a negative attitude toward methodology studies		.80			
16. Methodological books are hard to understand		.32		.49	.59
17. Methodology courses need more work than other courses				.70	
Eigenvalues	4,31	2,52	1,92	1,19	1,16
Cronbach's Alpha's for selected variables	.78	.71	.71	.70	.60

Note. Decimal places and loadings less than .30 are omitted. Items selected for sum variables are underlined.

Analyses of variance between the major groups (education, psychology and sociology) were conducted to find out possible differences between the groups. The major groups did not differ from each other on any difficulty sum variable. It also follows that the students in different courses, i.e. qualitative or quantitative, did not differ from each other in their answers.

Relations among experienced difficulty and achievement variables

The Pearson product moment correlations between experienced difficulty sum variables, high school mathematics achievement, university statistics and quantitative methods grades are shown in Table 2.

Table 2. *Correlations among experienced difficulty sum variables, high school mathematics achievement, university statistics and quantitative methods grades (N = 74)*

Variable		1	2	3	PC1	PC2	PC3	PC4
1.	High school maths							
2.	Statistics	.32*						
3.	Quantitative methods	.22	.32*					
PCI	Instruction	-.05	.00	-.15				
PC2	Interest	-.18	.12	-.16	.05			
PC3	Superficiality	-.10	.02	-.13	.32*	.21		
PC4	Ability	-.37*	.10	.03	.28*	.25*	.09	
PC5	Unconnection	.00	.10	-.09	.55*	.01	.30*	.38*

Note: $p < .05$*

High school mathematics grade had a positive correlation with statistics university grade, but no correlation with quantitative methods university course grade. Statistics and quantitative methods grades were intercorrelated, but they were not connected to experienced difficulty sum variables. This implies that the experienced difficulties in quantitative methods and statistics courses are not necessarily connected to the achievement on these courses (see also Figure 2).

Mathematics high school grade was connected to the Ability sum variable. This means that the previous achievement in mathematics is connected to the students' experience of themselves as learners of mathematical subjects. Mathematics high school grade was not connected to other difficulty sum variables. The difficulty sum variables were interconnected to each other.

Discussion

The results of this study on difficulties in quantitative methods courses were quite similar to the results of the previous studies on statistics anxiety. The results are also shown in Figure 2 in comparison to the Figure 1. Previous achievement in high school mathematics had some connection to university methods course achievement, but the connection was not strong. Earlier mathematics achievement turned out to be connected to only one kind of difficulty in quantitative methods learning, i.e. the way the students see themselves as learners of mathematics-related subjects. None of the experienced difficulties correlated with achievement at university.

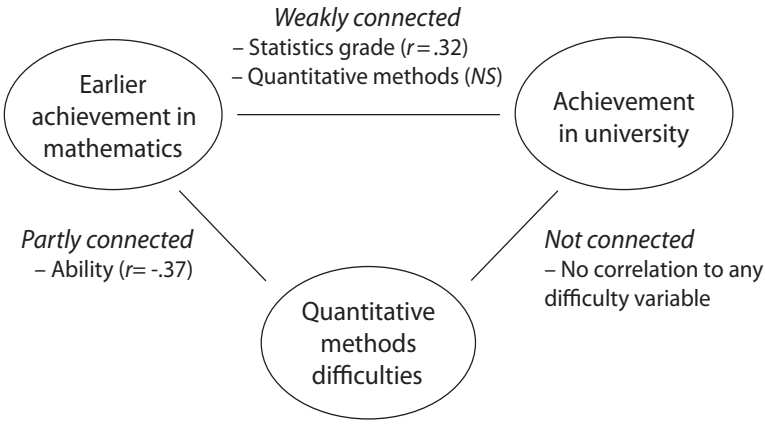

Figure 2. *Relationships between earlier achievement in mathematics, quantitative methods difficulty, and achievement in university quantitative methods related courses.*

The result that earlier mathematics achievement correlated with the way the learners see themselves as learners of mathematics may refer to the influence of previous experiences with mathematics (e.g. Schoenfeld, 1989). However, the correlation was not very strong, so there might also be other reasons for the negative conceptions of one's own mathematical and technical ability. The roots of beliefs in mathematical and technological domains may lie in broader conceptual and cultural structures, rather than individual bad prior experiences with mathematics. They might, for example, lie in something called the cultural conception of "hard" and "soft" values. Murtonen and Lehtinen (2003) found that people who thought languages were easy for them tended to view quantitative meth-

ods as not easy (that is, they were negatively correlated). Languages is just one example, but there might also be other areas that the students conceptualise according to the common distinction between "hard" and "soft" studies. These kinds of concepts may have an impact on people's behaviour somewhat like underlying framework theories that influence the understanding and conceptualising of more specific issues (e.g. Vosniadou, 1994). For example, some social science students may think they are not good at or do not want to commit themselves to mathematical subjects, and thus experience difficulties in these domains.

The students experienced the least problems in connection with their interest in quantitative methods. In other words, the students themselves experienced more problems with the instruction and the domain of quantitative methods learning than with their own interest. Motivational and conceptual reasons for difficulties may thus not be the only reasons for difficulties; in the future we should carefully study the problems in learning arising from instruction and the subject of quantitative methods.

Many intercorrelations were found among the experienced difficulty sum variables. The different types of difficulties thus seem to form a connected web. A student who experiences difficulties in one sector is more likely to experience difficulties in other sectors, too.

Earlier mathematics achievement was measured in this study by self-reported high school mathematics grades. There is a possibility of not getting reliable results, because students may not remember their grades accurately, or may actively bias their estimate (under- or overestimating it). The method was used in this study because gaining access to the previous grades would have been very difficult, especially because of the problem with information security. The method of asking students about their mathematics grade has, however, been used successfully in other studies (e.g. by Birenbaum & Eylath, 1994).

Another limitation was that we used the information of the university student register information to evaluate the students' performance in university courses, and this is a rather broad measure. For more elaborate analysis of the relation between the experience of difficulty and quantitative methods performance, it might be better to use some specific knowledge tests. It may be that students try to attain good grades in spite of experienced difficulties or negative attitudes.

In the study by Townsend et al. (1998), mathematics self-concept and anxiety were not associated with achievement. They concluded that this does not mean that we should be unconcerned about them, because students' beliefs and attitudes influence not only their enjoyment of the subject but also the likelihood that they will select it for further study. Similarly in this research, the fact that the experience of difficulty was

not related to achievement in university courses does not mean that there are no consequences. It is possible that these already highly selected students have developed methods needed for gaining good results in their courses, independently of their motivation, beliefs and attitudes. The real consequences might appear later in further course selections or in their working life. The impacts from negative self-beliefs and experiences of difficulty on later behaviour need to be further studied. Interesting avenues to explore include students' conceptions of their future work and the need of research skills in it, the types of jobs and responsibilities people take on after their studies, and the ways in which they use statistical information and deal with research results in these jobs.

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References

Betz, N. E. (1978). Prevalence, distribution, and correlates of math anxiety in college students. *Journal of Counseling Psychology* 25, 441–448.

Birenbaum, M., & Eylath, S. (1994). Who is afraid of statistics? Correlates of statistics anxiety among students of educational sciences. *Educational Research* 36, 93–98.

Clute, P. M. (1984). Mathematics anxiety, instructional method, and achievement in a survey course in college mathematics. *Journal for Research in Mathematics Education* 15, 50–58.

Filinson, R., & Niklas, D. (1992). The research critique approach to educating sociology students. *Teaching Sociology* 20, 129–134.

Forte, J. (1995). Teaching statistics without sadistics. *Journal of Social Work Education* 31, 204–308.

Garfield, J., & Ahlgren, A. (1988). Difficulties in learning basic concepts in probability and statistics: Implications for research. *Journal for Research in Mathematics Education* 19(1), 44–63.

Hauff, H. M., & Fogarty, G. J. (1996). Analysing problem solving behaviour of successful and unsuccessful statistics students. *Instructional Science* 24, 397–409.

Lehtinen, E., & Rui, E. (1995). Computer-supported complex learning: An environment for learning experimental methods and statistical inference. *Machine-Mediated Learning* 5(3&4), 149–175.

Murtonen, M., & Lehtinen, E. (2003). Difficulties experienced by education and sociology students in quantitative methods courses. *Studies in Higher Education* 28, 171–185.

Murtonen, M. (2001, August). *Conceptions of research methodology, consistency of conceptions and experienced difficulties on quantitative methods courses*. Paper presented at the EARLI Biennial Meeting, Fribourg, Switzerland.

Newstead, K. (1998). Aspects of children's mathematics anxiety. *Educational Studies in Mathematics* 36, 53–71.

Onwuegbuzie, A. J., & Daley, C. E. (1998, April). *The relationship between learning styles and statistics anxiety in a research methodology course*. Paper presented at the annual conference of the American Educational Research Association, San Diego, U.S.A.

Pretorius, T. B., & Norman, A. M. (1992). Psychometric data on the statistics anxiety scale for a sample of South African students. *Educational & Psychological Measurement*, 52, 933–937.

Rosenthal, B. C., & Wilson, W. C. (1992). Student factors affecting performance in an MSW research and statistics course. *Journal of Social Work Education* 28, 77–85.

Resnick, H., Viehe, J., & Segal S. (1982). Is math anxiety a local phenomenon? A study of prevalence and dimensionality. *Journal of Counseling Psychology* 29, 39–47.

Schoenfeld, A. H. (1989). Explorations of students' mathematical beliefs and behavior. *Journal for Research in Mathematics Education* 20, 338–355.

Thompson, B. W. (1994). Making data-analysis realistic: Incorporating research into statistics courses. *Teaching of Psychology* 21(1), 41–43.

Townsend, M. A. R., Moore, D. W., Tuck, B. F., & Wilton, K. M. (1998). Self-concept and anxiety in university students studying social science statistics within a co-operative learning structure. *Educational Psychology* 18, 41–54.

Vosniadou, S. (1994). Capturing and modelling the process of conceptual change. *Learning and Instruction* 4, 45–69.

Zeidner, M. (1991). Statistics and mathematics anxiety in social science students: some interesting parallels. *British Journal of Educational Psychology* 61, 319–328.

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Sammanfattning

I denna undersökning studerades samband mellan prestationerna i matematik i gymnasiet, prestationerna i universitetskurser i statistik och i kvantitativa metoder och upplevda svårigheter i kurser i kvantitativa metoder. Tidigare prestationer i matematik korrelerade med prestationerna i universitetskurser i statistik, men inte med prestationerna i kurser i kvantitativa metoder. Tidigare prestationer i matematik uppvisade ett samband med upplevd egen förmåga i matematik och i kurser i kvantitativa metoder, men inte med andra upplevda svårigheter. Vidare uppvisade upplevd egen förmåga i matematik och i kurser i kvantitativa metoder samband med andra upplevda svårigheter i kurserna i kvantitativa metoder. Det fanns inte något samband mellan upplevda svårigheter och prestationerna i universitetskurserna.