NOVICES' AND EXPERTS' KNOWLEDGE ON STATISTICS AND RESEARCH METHODOLOGY

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Abstract

Many social science students in university constantly experience difficulties with research methodology and statistics courses. In this study we compared novice students', advanced students' and experts' knowledge on these complex and difficult domains. The results of the study refers to a tendency for novices, especially when they have had problems with mathematical subjects, to place the contents to emotional or other irrelevant categories which restricts or blocks their other cognitive activities on these subjects. There was a remarkable difference in the fragmentation of concept maps and explanations between novices, advanced students and experts. The novices were also not able to use sufficient representations to understand the concepts.

Introduction

Research methodology and statistics courses are constantly experienced as difficult by many university social science students (Filinson & Niklas, 1992; Forte, 1995; Lehtinen & Rui, 1995; Murtonen, 2000). When learning research methodology and statistics, students often face the situation when they for example may have some everyday experiences of statistical phenomena and implicit conceptions or "theories" of these phenomena, but they cannot relate these experiences to their studies. Their statistical knowledge may be composed of fragmented and isolated pieces, which do function at a sufficient level in specific situations, but do not connect the phenomenon into a wider context. Students may also try to understand the concept on the basis of the surface structure of the name of the concept. It is also possible that an integrated whole of statistical concepts is not possible to attain without enough operational understanding and experiences of the methods (Sfard 1991).

According to Chi (1992), conceptual change occurs when concepts are transferred from one ontological category to another. In Chi's model, the ontological entities belong to different ontological categories. This refers to an objectivist, Aristotelian ontological assumption that the categories exist in the world. In contrast, cognitive theories suggest that categories do not exist in the world, but in the humans' minds. According to Lakoff's and Johnson's (Lakoff, 1987, Lakoff and Johnson, 1999) embodied philosophy, categories are humans' way of behaving in the environment. On the basis of this theory we assumed that there might be several categories in humans' minds, which vary from person to person. There might also be emotional categories like "difficult things" that students form on the basis of their experiences. For example, if a student has experienced difficulties with mathematics, he or she might have placed the whole subject into a category of difficult or unpleasant things. Later, they may place statistics into this same category, because

statistics reminds them of mathematics. This kind of a categorisation seems to function as an obstacle to other cognitive activities.

According to Núñez, advanced mathematical abilities are not independent of the cognitive apparatus used outside of mathematics. Rather, it appears that the cognitive structure of advanced mathematics makes use of the kind of conceptual apparatus that is the stuff of ordinary everyday thought such as image schemas, aspectual schemas, conceptual blends, and conceptual metaphor. (Núñez, 2000.) Similarly, to understand statistical phenomenon students should be able to relate them to their everyday experiences and thoughts.

The aim of this study is to compare novice students', advanced students' and experts' conceptions of research and statistical concepts in order to find the major differences between them. We hypothesise that novices, especially when they have mathematical problems, do place contents to emotional or other irrelevant categories that block other cognitive activities, while those with more positive experiences do not do so. We also assume that novices' knowledge is more fragmented than experts' knowledge, and that they lack operational understanding and experience and because of that they try to understand concepts on the basis of the surface structure, and that they are less capable of using representations and metaphors to help understanding.

Method

This study consisted of two phases. In the first phase, a questionnaire was filled in by 31 education students in the beginning of a statistics course. Two questionnaires were used. The first one was a test of statistical content knowledge measuring the understanding of e.g. mean, deviation, correlation and statistical inference. Students were also asked to estimate their certainty in each of the tasks. The other questionnaire dealt with students experienced difficulties in quantitative research methods, attitudes on research and learning orientations. On the basis of these questionnaires, four students were selected for further research. Two of the chosen students succeeded well in the statistical test, were confident in doing the tasks, did not experience difficulties in quantitative methods, had positive attitude towards the methods and their orientation was deep and task oriented. They will be called the 'advanced students' because of their good success in the statistics tasks. The other two students had considerable problems in the statistics tasks, had experienced difficulties in quantitative methods and they were not confident in the tasks. They will be called the 'novice students'. They experienced problems in learning quantitative methods and they did not appreciate the methods. They were not deep oriented toward learning methodology but were more self-defensively oriented and less task oriented than the other two students.

In the second phase these four students were interviewed after the statistics course. We also interviewed two experts to be able to compare the students' answers to an expert view. The experts were psychologists who had been working as researchers for many years. All interviewees were female. The interviews were conducted in pairs on each expertise level. Both two researchers were present all the

time. The interviews lasted from 1 to 2 hours. The reason for interviewing two students/experts at the same time by two researchers was to encourage a discussion between students and also between students and researchers.

The interview was about conceptions of scientific research and statistics. The interviewees were asked to explain what scientific research is and simultaneously to draw a concept map of scientific research. During and after drawing a concept map the students were asked questions concerning their attitudes and conceptions of different domains of scientific research and especially about statistics. Specific questions about statistics were asked on what they think that happens in a t-test and do they know what the p-value really stands for.

Results

A category of difficult things

In the questionnaires we asked the students about the difficulty of quantitative method courses. In order to confirm that we found the students we were looking for, we asked the students in the interviews about their experiences. We started with novice students:

> *Interviewer:* How do you experience research methodology as a subject to be learnt?
>
> *Laura:* It feels more difficult than other courses. It might be that when one specific subject is easy to learn, then this [methodology] is kind of a clump. It somehow frightens. It feels somehow foggy and difficult to learn.
>
> *Interviewer:* Does it include the whole research or just some specific domain?
>
> *Laura:* I cannot figure out the specific domains, but as a whole. Just the research - everything else feels detached from it.
>
> *Emma:* Well, at least statistics feels very difficult. It would be good to have a link from it to something more practical. It has now got a bit clearer, when I have been doing my practice work, but at the beginning it was really hard.

Laura's notion about the research being a clump seems to be a good example of a category of difficult things. She has no tools for managing research domain and she is also frightened about it. She cannot even name a domain inside methodology that is the most problematic. When Emma identifies statistics, Laura agrees with her. Laura refers to other study subjects which are comprehensible to her as independent domains, but methodology represents to her a domain that she cannot link to the other study subjects and she cannot understand the subdomains of research methodology. Emma mentions that things have become clearer when she has been working with her practise work, which refers to the importance of practise and operational activity in the elementary understanding of statistical concepts. The advanced students had a very different view on methodology and statistics:

> *Maria:* Well, if you think about statistics, you sure have to work on them, but I haven't had any problems that I couldn't have overcome. Rather, I would say it's refreshing, to have something else, something different. I have always liked mathematics, for to have something else, too.

> *Jenny:* And it is different from… if you think about our major subject in general, it's much about building up aggregate domains and understanding things, but here you have to learn also by heart what they mean and think how they are connected. It's not difficult. Maybe demands more work, but it's not more difficult.

In Maria's comment there is a reference to positive experiences with mathematics and she even talks about statistics as a 'refreshing' part of her studies. In Jenny's comment there is a reference to the difficulty of the subject but also a confident reassurance that she is going to work to be able to comprehend the things. She did not find the work impossible.

Concept maps

The concept maps of the student pairs and the experts were very different from each other. The maps are shown in Figures 1-3. The advanced students started to do the given task eagerly and they were confident about what they were doing. The experts asked if we wanted some specific kind of a map or can they just draw what they want (they were told to draw what they want). The novice students were worried about how they will do and they didn't know where to begin. They were asked to just start somewhere to write concepts on the paper. The concept map they produced was more fragmented than the others' map. It did not have as much content as advanced students' map and the concepts were just floating it the air. The map did not show much logic in the placement of the concepts. The advanced students did have a coherent structure that proceeded chronologically in the same sequence as ideal research. They drew first a small map of principles in science and then they were asked to think about practise also. They drew a different map of research in practise, but they said in the interview that these two could have been drawn in the same map.

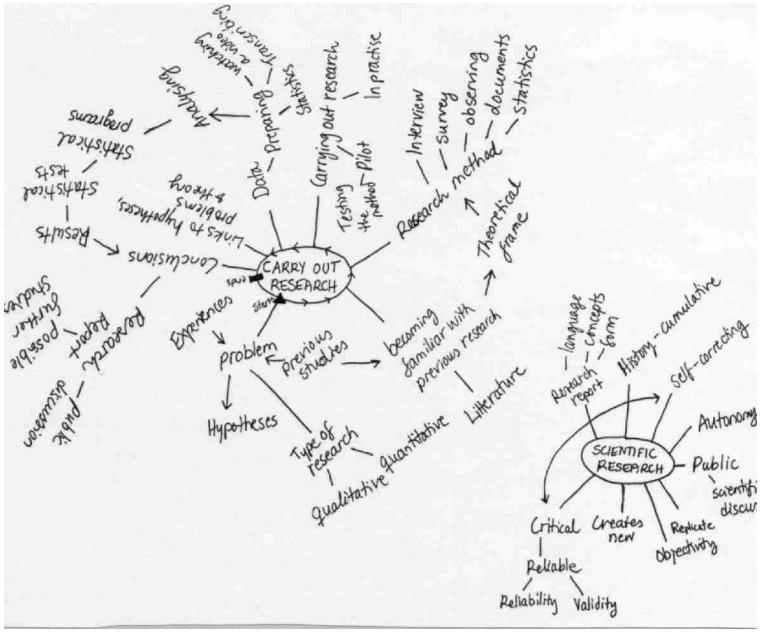

FIGURE 1. Advanced students' concept map.

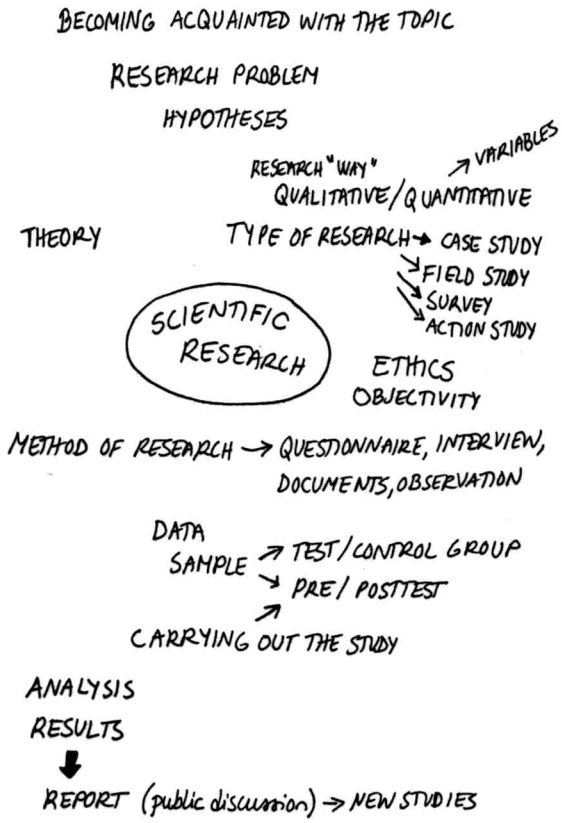

FIGURE 2. Novive students' concept map.

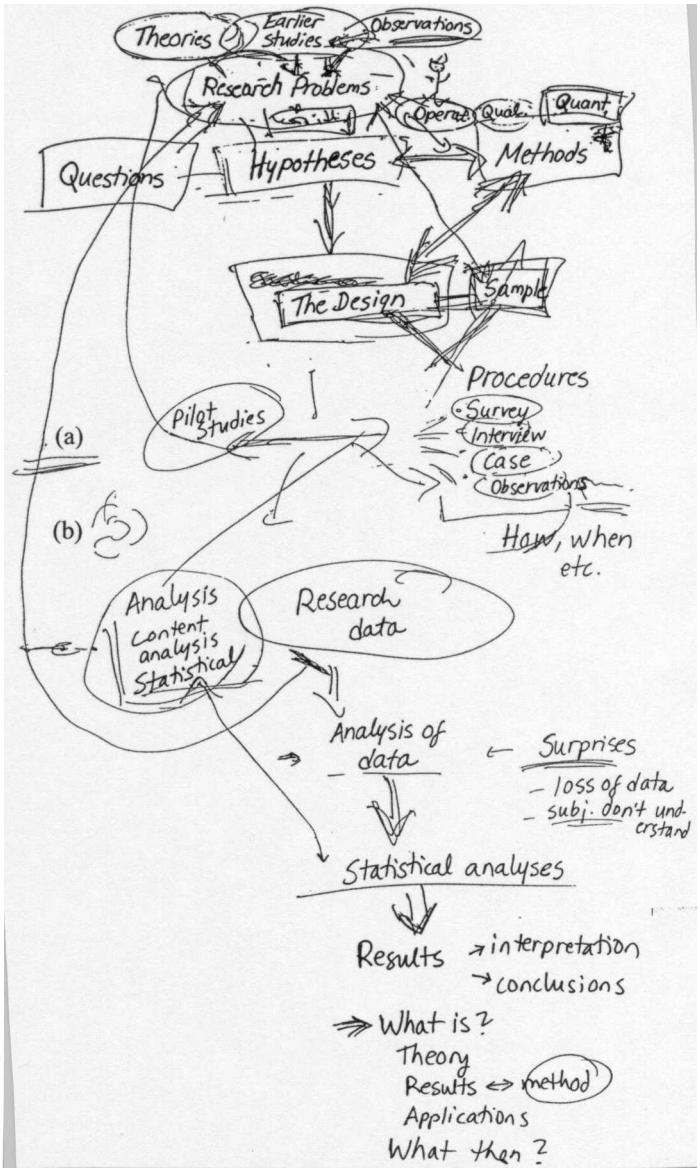

FIGURE 3. Experts' concept map.

The experts' concept map had many dimensions. They constantly talked about "interaction" between the subdomains and they also drew lines and arrows to describe the interaction:

> *Eva:* And these are, of course, constantly interacting with each other. You cannot draw a research like this. [Eva drew the pattern (a) in Figure 3]
> *Irma:* Yes, you cannot.
> *Eva:* Instead, it is something very complicated… [Eva drew the pattern (b) in Figure 3]

Although the advanced students did have lots of connections between the concepts in their map, they did not talk about the interaction between the domains. The experts

mentioned that it is difficult to draw a figure of research, because it does not progress linearly. They ended up with a conclusion that research has to be organized somehow to be able to report it and thus it can be represented as a product. According to them, research description is like schemata that frame the research processes. Research report also gives opportunity to replicate the study, which in turn is an important tool for assessing the validity and reliability of a research. The experts noticed that research problems can rise from many different view points. They drew a researcher in the right upper corner of the concept map to point out that it depends on the researcher's individuality how he or she does the research. The student pairs did not mention the impact of an individual researcher.

While both of the student pairs always sought for a conception that they could both agree about, the experts did not consider it a problem to have a different conception about some issues. In the end they concluded that this concept map represented only a small piece of scientific research, which is an activity of a research community and some local research groups with their own activities are just a small part of the bigger unit. They thus saw research as a very wide concept, while students only saw it as one practical research project.

> *Eva:* And here we get to our beloved, research design
> *Irma:* I thought it goes here with these (shows the methods)
> *Eva:* Well, not quite… actually
> *Irma:* Well, for me it belongs there
> *Eva:* Ok, you could put it there if you were writing a section about research methods
> *Irma:* Yes, then it would be it's own section below the methods.
> *Eva:* For me this (research design) is a very important part. This is the core of the reasoning when we are building up the research logic.

The maps and the processes that the researchers saw when the students drew the maps suggest that the novice students did not have a clear conception about how research proceeds in practise.

Representations of statistical concepts

The novice students were asked if they are familiar with t-test. They said it was introduced superficially, but they did not know it very well. Then the interviewer asked if they knew what the p-value stands for. The students had just finished a statistics course, where they had studied the p-value, so they should have been familiar with it. We had the following conversation:

> *Emma:* I was just looking for the practice work, well, it (p-value) is a kind of, I mean, how it goes…
> *Laura:* … significant and almost significant…
> *Emma:* Well, that how they go, all the commas and nulls and others… I asked about it in a statistics lecture and the teacher tried to explain. She wrote this awful formula on the

blackboard and explained that it is based on that and there is some theoretical thing in the computer and it comes from all of these… and … (laughing) it is not clear to me…
Interviewer: Is it somehow mystical?
Emma: No, it has been explained
Laura: Yes, it has been explained that, how it goes… But, when you should explain it in the results… It is quite easy to look it from the papers, that what is significant and so, but, strictly speaking, I don't get it at all.
Emma: Those certain numbers are in all of them, I mean that p is smaller than this and this, well, the significant is easy, but when it gives you all the numbers, then I cannot understand where these all numbers belong to.

The conversation above shows again how unconfident the novice students are about their knowledge and also how fragmented and fuzzy their knowledge is. When talking about t-test with the advanced students, Maria explains about two groups and simultaneously keeps her both hands in the air in front of her as to show two groups. The interviewer asks what the hands represent:

Maria: Well, t-test reminds me about two groups
Interviewer: Do you see some kind of distribution figures in your mind?
Maria: No, I don't

When we asked the same question about t-test from the experts, they grasped pens eagerly and wanted to draw. They were, however, first asked to explain without paper and pencil. They showed similar hand representations as the advanced student did when she was describing the comparison groups. When allowed to draw, the experts drew two distribution lines partly overlapping each other. They had thus helpful representations about the asked test.

Discussion

The interviews showed that we succeeded to find with our questionnaires a pair of novice students, who had problems with statistics content knowledge and also attitudinal problems, and a pair of students who were good with the content knowledge and did not have attitudinal problems. The interviews about the difficulty of methodology referred to the tendency of some students to create a category of difficult things, a "clump", where they place all things they think that are not possible for them to learn. This kind of a categorisation seems to function as an obstacle to further cognitive activities. The novice students also called for more practices, which suggests that they suffer from the lack of operational understanding and helpful representations of the concepts.

The major difference in the concept maps of the interviewees was their state of fragmentation. The map of the novices was a static picture composed of fragmented pieces of external knowledge with hardly any connections between them. The map of the advanced students had more structural elements, connections between the

domains and indications of a process' like knowledge, even some dynamics. There was, however a noticeable difference between the concept maps of the students and the one of the experts. The map of the experts formed an integrated whole of the research, which was clearly structured but simultaneously had the dynamics of the research in action. Besides the formal knowledge of research methodology there was also a vision of the important informal knowledge reflecting the experience of the experts. The experts had also clear ways of representing the given statistical concepts, while novices had hardly any indications of representations.

The most important finding of this study was the evidence of a category of difficult things, which the novice students had, but the more advanced did not have. We suggest that this kind of mental categorisation might be one of the serious challenges to the learning of statistical methods. In order to support the learning in this kind of a complex domain, deliberate teaching arrangements are needed to help student to reassign the "difficult" things into a category of "possible for me to learn" things.

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