Teachers' concepts of spatial scale. An intercultural comparison between Austrian, Taiwanese, and US-American teachers.

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Abstract: In the science curricula of various countries, scale receives an important place in middle as well as in high school science education. This study explored scale concepts of inservice and preservice teachers from three countries, Austria, Taiwan, and the USA. Accuracy of scale concepts differed in the samples of the three countries. The Austrian and Taiwanese samples held more accurate concepts of scale than the U.S. sample. Inservice teachers had more accurate concepts than preservice teachers.

Introduction

There are powerful ideas that stretch across all the science domains. One of these prevailing ideas is scale. Scale encompasses not only variables such as size and distance but also includes other variables such as time, weight, and temperature. Scale is very important in science because the properties of materials change as the magnitude of scale increases or decreases. As the American Association for the Advancement of Science has pointed out, it is crucial for students to develop an understanding of the "immense size of the cosmos, the minute size of molecules, and the enormous age of the earth (and the life on it)" (AAAS, 1993, p. 276).

This study examined teachers from three different countries (Austria, Taiwan, and the USA). In the curricula of all three countries, scale receives an important place in middle school and high school science education (Austrian Federal Ministry of Education, Arts, and Culture, 2009; Ministry of Education, 2009; State Board of Education, 2009). With regard to middle school students' knowledge of scale, the three countries differed strongly from each other in the PISA studies. Concepts of scale were mainly measured in the mathematics part of the PISA studies and are regarded as basic concepts of mathematical education. In the 2006 PISA studies, students in Taiwan received the best rank of 57 countries when mathematical knowledge was measured. Austria was 18th, the USA 35th (OECD, 2006). In this study, the accuracy of scale concepts of teachers from the three countries was investigated. Students in preservice teacher programs (novice teachers) and inservice teachers (experienced teachers) participated. In the study, differences between the three countries as well as differences between novice and experienced teachers were explored.

Methodology

Participants in this research study included secondary science teachers drawn from two different countries that use metric in everyday contexts: Austria (n = 101), and Taiwan (n = 59) who volunteered to be part of the study. The concepts and experiences of these teachers were compared to teachers from the United States (n = 66) from a previous study of teachers' concepts of size and scale (Jones, Tretter, Taylor, & Oppewal, 2008) for a total of 226 teachers (131 females, 95 males). Participants were recruited from undergraduate and graduate teacher education programs and area schools.

All participants of the study completed two assessments designed to examine conceptual categories of size and scale accuracy. These assessments included the Scale Anchoring Objects (SAO) and the Scale of Objects Questionnaire (SOQ). The SAO assesses representative objects that participants use for conceptual understanding at a variety of scales from a nanometer to a billion meters. The instrument asks participants to generate objects representative of different size scales (nm, µm, mm, cm, etc.). The SAO reflects a number line of sizes that participants mentally hold (Jones, Tretter, Taylor, & Oppewal, 2008). The accuracy of a participant's understanding of scale was measured by the number of correct answers in four ranges, the nanometer to millimeter range (nm – mm), the centimeter to meter range (cm – m), the 10 meter to 1000 meter range (10m – 1000m), and the million to billion meters range (million – billion m). The SOQ assesses perceived sizes of a variety of objects. From a list of options spanning less than a nanometer to over one billion meters, participants indicate which scale range each object falls within. The instruments indicates which scale sizes are well distinguished from each other and where in the size continuum individuals conceptualize distinctly different categories of scale (Jones et al., 2008). The accuracy of a participant's understanding was measured by the number of correct answers in four ranges, nm – mm, 1mm – m, 1m – 1000m, million m – billion m.

Results

Scale Anchoring Objects

A multivariate analysis of variance with the factors nationality (Austria, Taiwan, USA) and experience (novice versus experienced teachers) was carried out. Dependent variables were the number of correct answers in the four ranges of scale. The analysis yielded a highly significant difference between the three nationalities ($F_{20, 406} = 8.355$; $p < .01$). According to post-hoc Tamhane tests, Austrian and Taiwanese participants gave significantly more correct answers than US-american participants in three ranges: nm – mm, 10m – 1000m, million – billion m. The Taiwanese sample scored significantly better than the Austrian sample in the nm – mm range, the Austrian sample scored significantly better than the Taiwanese sample in the 10m – 1000m range. There were no differences in the number of correct answers in the cm to m range. The MANOVA showed neither a main effect for the factor experience ($F_{20,202} = .999$; $p > .5$) nor an interaction effect ($F_{20,406} = .142$; $p > .5$).

Scale of Objects Questionnaire (SOQ)

A multivariate analysis of variance with the factors nationality and experience was carried out. Dependent variables were the number of correct answers in the four ranges of scale. The analysis yielded a highly significant difference between the three nationalities ($F_{10, 430} = 5.413$; $p < .01$). In all four ranges the Austrian sample scored significantly higher than the US sample as post-hoc Tamhane tests showed. Taiwanese teachers gave more correct answers than the American teachers in all ranges except the >1m – 1000m range. The Austrian sample gave significantly more correct answers than the Taiwanese sample in the >1m – 1000m range. The multivariate analysis of variance also showed a significant main effect for the factor experience ($F_{10, 430} = 2.210$; $p < .5$). Inservice teachers gave more correct answers in the >1m – 1000m and >million – billion m range than preservice teachers. There was no interaction between nationality and experience ($F_{15, 648} = 1.014$; $p > .5$).

Table 1 and 2: Mean values for SAO and SOQ for three nationalities

	SAO		
	Austria	Taiwan	USA
nm to mm	66.1	76.9	34.0
cm to m	99.4	100.0	94.2
10m to 1000m	98.0	91.3	92.6
mil to bil m	67.3	66.0	35.7

Note. Values are mean percentages of correct answers

	SOQ		
	Austria	Taiwan	USA
nm to mm	66.1	63.3	52.2
>1mm – m	84.3	77.9	601.
>1m – 1000m	88.9	73.9	69.1
>mil – bil m	64.0	60.4	46.2

Discussion

The results of the SAO analyses showed there were significant differences between the three countries in all ranges except the cm to m range. This range reflects sizes and objects which are usually encountered in daily life and which can be experienced directly by seeing and/or touching. In contrast, the nm – mm and the million – billion m range reflect objects and sizes which are encountered in academic contexts. In these ranges, the differences in concept accuracy reflect the results of the PISA study: The Austrian and Taiwanese samples consistently received higher scores than the U.S. sample. It seems that differences in accuracy of concepts are established in school and remain stable even in experienced teachers. Furthermore, in all countries, inservice teachers had more accurate concepts for large sizes. It seems that preservice teachers have more difficulty in conceptualizing scales beyond the human realm and that accuracy of concepts is further developed by professional teaching experiences.

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