POWERS OF THE UNIVERSE: A LEARNING SEQUENCE AND LOGARITHMIC BOOK FOR TEACHING EXTREME NUMBERS

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KEYWORDS: Logarithmic thinking, Scale of the Universe, activity-based learning

BACKGROUND

In the modern world, public discourse increasingly involves extreme numbers, whether it be trillions of dollars, terabytes of computer memory, parts per billion of pollutants, billions of light years to a newly discovered galaxy, or nanometer wire sizes in the latest computer chips. There is widespread recognition of the need for corresponding improvements in comprehension of extreme numbers. This requires a change in focus from the linear mental number line to the logarithmic number line in which intervals are powers of ten. Following evidence that young minds may be naturally attuned to logarithmic thinking, it is suggested that logarithmic thinking skills should be developed from an early age, using appropriate methods and activities.

AIMS

The aim of this research is to develop and test a program designed to establishing a logarithmic sense of scale in students over age range from 7 to 14 years old. We aim to determine age dependence of learning outcomes and assess the benefits of using a logarithmic activity book.

DESCRIPTION OF INTERVENTION

We present a six-hour sequence of learning activities designed to establish logarithmic thinking. The sequence begins with activities focused on doubling, in which powers of two notation is introduced. This transitions to powers of ten, in which we focus on extreme numbers associated with the scale of the Universe. During part of each lesson and in homework, students make entries into an interactive logarithmic book, *Powers of the Universe*, specifically designed for this program. Each page of the book is numbered to represent a power of ten, ranging from -37 to 90, sufficient to encompass most numbers and magnitudes (in SI units) of everything in the universe. Students use internet searches and estimation (rounding and powers of ten) to determine page numbers for things such as size of a proton (p -15), number of atoms in the Sun (p 57), the age of the Universe (p 18) and the mass of a neutrino (p -37). Color-coded bands identify units such as mass, time, energy and numbers.
We report an intervention for 66 middle school students, totaling 6 hours.

DESIGN AND METHODS

The sequence of activity-based lessons, combined with the *Powers of the Universe* book were designed and developed following the theoretical Model for Education Reconstruction using rounds of feedback and improvement. Pre-test/post-test methods, statistical tests and participant feedback were used to assess the program.

RESULTS AND CONCLUSION

Our findings suggest that the program effectively enhanced students' understanding of the extreme scale of the Universe. We observed substantial statistically significant improvements across all student ages. Over 80% of students were able to use logarithmic reasoning to comprehend extreme numbers across a broad magnitude range, and analyze exponential doubling such as virus spreading or the increasing power of quantum computers. Students showed exceptional enthusiasm towards filling out their logarithmic books and encompassing the entire universe in a small book.

Proceedings of the Australian Conference on Science and Mathematics Education, The University of Canberra, 18 – 20 September 2024, page 68, ISSN 2653-0481.