World Academy of Science, Engineering and Technology
International Journal of Computer and Information Engineering
Vol:13, No:06, 2019

Development of an Artificial Neural Network to Measure Science Literacy Leveraging Neuroscience

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Abstract : Faster growth in science and technology of other nations may make staying globally competitive more difficult without shifting focus on how science is taught in US classes. An integral part of learning science involves visual and spatial thinking since complex, and real-world phenomena are often expressed in visual, symbolic, and concrete modes. The primary barrier to spatial thinking and visual literacy in Science, Technology, Engineering, and Math (STEM) fields is representational competence, which includes the ability to generate, transform, analyze and explain representations, as opposed to generic spatial ability. Although the relationship is known between the foundational visual literacy and the domain-specific science literacy, science literacy as a function of science learning is still not well understood. Moreover, the need for a more reliable measure is necessary to design resources which enhance the fundamental visuospatial cognitive processes behind scientific literacy. To support the improvement of students' representational competence, first visualization skills necessary to process these science representations needed to be identified, which necessitates the development of an instrument to quantitatively measure visual literacy. With such a measure, schools, teachers, and curriculum designers can target the individual skills necessary to improve students' visual literacy, thereby increasing science achievement. This project details the development of an artificial neural network capable of measuring science literacy using functional Near-Infrared Spectroscopy (fNIR) data. This data was previously collected by Project LENS standing for Leveraging Expertise in Neurotechnologies, a Science of Learning Collaborative Network (SL-CN) of scholars of STEM Education from three US universities (NSF award 1540888), utilizing mental rotation tasks, to assess student visual literacy. Hemodynamic response data from fNIRsoft was exported as an Excel file, with 80 of both 2D Wedge and Dash models (dash) and 3D Stick and Ball models (BL). Complexity data were in an Excel workbook separated by the participant (ID), containing information for both types of tasks. After changing strings to numbers for analysis, spreadsheets with measurement data and complexity data were uploaded to RapidMiner's TurboPrep and merged. Using RapidMiner Studio, a Gradient Boosted Trees artificial neural network (ANN) consisting of 140 trees with a maximum depth of 7 branches was developed, and 99.7% of the ANN predictions are accurate. The ANN determined the biggest predictors to a successful mental rotation are the individual problem number, the response time and fNIR optode #16, located along the right prefrontal cortex important in processing visuospatial working memory and episodic memory retrieval; both vital for science literacy. With an unbiased measurement of science literacy provided by psychophysiological measurements with an ANN for analysis, educators and curriculum designers will be able to create targeted classroom resources to help improve student visuospatial literacy, therefore improving science literacy.

Keywords : artificial intelligence, artificial neural network, machine learning, science literacy, neuroscience
Conference Title : ICAIE 2019 : International Conference on Artificial Intelligence and Education
Conference Location : New York, United States
Conference Dates : June 04-05, 2019