

DEVELOPMENT AND VALIDATION OF AN INSTRUMENT TO MEASURE UNDERSTANDING OF NANO¹

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With integration of nanoscience and nanotechnology into everyday life, it is important that the public has a scientific foundation upon which to evaluate their perceived hopes and fears of 'nano'. Various tools assess attitudinal and affective dimensions of nano, but little research has been directed to instruments to evaluate the conceptual knowledge aspect of public nano understanding. This paper describes the design and validation of an instrument to measure conceptual knowledge of nano. A 28-item test was constructed around core nano-concepts and administered to 302 participants. Factor analysis revealed a single latent variable interpreted as a general "nano-knowledge" construct. High internal consistency of the questionnaire was indicated by a Cronbach's alpha value of 0.91. Mean score on the questionnaire was 15.3 out of 28 (54.5%) with item difficulty indexes ranging from 0.19 to 0.89. High discriminatory power of the instrument was indicated by discrimination values greater than 0.4. Analysed psychometric properties suggest that the Nano-Knowledge Instrument (NanoKI) is a valid and reliable tool for assessing nanorelated knowledge. Potential conceptual difficulties related to relative size of the nanoscale, random motion of nano-objects, and nanoscale interactions were revealed from a qualitative interpretation of response patterns, but are hypotheses in need of future inquiry. Promoting public understanding of nano could be supported by applying the NanoKI.

Keywords: Nanoscience and Nanotechnology, Nano-Knowledge Instrument (NanoKI), Public Understanding

INTRODUCTION

As applications of nanoscience and nanotechnology ('nano') emerge in nanomaterials and nanotherapies, it is crucial that the international public be involved in discussion regarding the societal implications of nano (e.g. Laherto, 2010). The inevitable impact of nano on society necessitates international citizens to make scientific judgments about perceived benefits and risks (Roco & Bainbridge, 2005). In science education it is becoming increasingly necessary to connect core discipline-based chemical, biological and physical based concepts to the nanoscale (e.g. Gilbert & Lin, 2013; Schönborn *et al.*, 2014). The last decade has seen the design of various instruments for diagnosing citizens' and learners' understanding of science. However, little attention (e.g. Lin *et al.*, 2013 in a Taiwanese context) has been given to validating psychometric tools focused on the conceptual knowledge dimension of nano per se: knowledge dealing with the scientific principles of nano.

Measuring nano-related knowledge can inform implementation of effective science communication channels for evaluating public understanding of nano, but a lack of valid instruments may impede this progress. The development of valid and reliable tests is seen as a crucial need for nano and scientific literacy at large. This study aims to design and validate an instrument for measuring conceptual knowledge central to nano.

¹ This symposium contribution summarises the original paper that is published in *Chem. Educ. Res. Pract., 2015, 16, 346-354.* The Nano-Knowledge Instrument (NanoKI) is available in the Appendix of the original source.



METHOD

Design of the Instrument

Literature synthesis (e.g. Stevens *et al.*, 2009) resulted in an inventory of propositional statements representing core understanding of nano. These statements were then iteratively transformed into conceptual "true or false" utterances culminating in a 28-item Nano-Knowledge Instrument (NanoKI) (see footnote on p.1).

Collection and Analysis of Data

A broad sampling strategy obtained 302 (139 females and 163 males, median age=36) responses to a web questionnaire linked to various social media and Blogs, representing an international sample from at least 20 countries. The 28 items were presented one at a time, and participants asked to "Indicate whether each of the following statements are true or false, or indicate if you do not know". Item readability was assessed with the Flesch-Kincaid measure. Item performance was analysed by calculating the proportion of correct answers (difficulty index) and mean difference between high scorers and low scorers (discrimination index D) for each item. Inter-item correlations deduced any negative and low correlations. Corrected item-total correlations and Cronbach's alpha if item deleted were calculated, and reliability of the test assessed from overall Cronbach's alpha. Construct validity was investigated by factor analysis with principal component analysis (PCA) to analyse the matrix of correlations. Multiple criteria were used to deduce the number of factors to retain.

RESULTS AND DISCUSSION

Validating the NanoKI

A mean score of 15.3 (SD=6.90, median=16) was obtained from the 28-item questionnaire (54.5% correct responses), ranging from 0 to 28. A Cronbach's alpha value of 0.907 indicates a high internal consistency. The Flesch-Kincaid test corresponds to typical reading level of a 16-18 year old (11.5th grade). Item

difficulty indexes ranged from 0.19 to 0.89. Three quarters of the items had difficulty indexes in the range 0.25-0.75, which indicates that the test is neither too easy nor too difficult overall. The correlation matrix showed that all item-item correlations were positive, and Cronbach's alpha was not improved by removing any of the items.

Factor analysis through PCA was supported by a Kaiser-Meyer-Olkin measure of sampling adequacy above 0.6 (0.917) and a significant result on Bartlett's test of sphericity (p<0.0005) (Tabachnick & Fidell,

2007). Six components with eigenvalues greater than 1 were extracted (Fig. 1), explaining 29.3% (eigenvalue 8.21) 5.6% (1.57) 4.8% (1.24) 4.0% (1.11) 3.8% (1.05)



Figure 1. Scree plot and parallel analysis used in factor analysis to determine the number of factors to retain.

8.21), 5.6% (1.57), 4.8% (1.34), 4.0% (1.11), 3.8% (1.05), and 3.7% (1.03) of the variance, respectively.

The scree plot (Fig. 1) shows a clear break after the first factor, indicating that only one factor should be retained. Although a Parallel Analysis indicated two latent variables in the data, a Minimum Average Partial test supported the scree analysis. The data structure is consistent with a single latent variable, all 28 items load onto the variable with loadings larger than 0.3, and it is interpreted as a general "nano-knowledge" construct.



Potential Conceptual Aspects of Response Patterns to Items

Regarding responses not coded as correct (45.5%), 10.9% were scientifically incorrect, while 34.6% indicated no knowledge of the answer (i.e. "Don't know"). A prevalent misunderstanding (e.g. Jones et al., 2013) was associated with relative size of the nanoscale, where 40% of respondents incorrectly suggested that "A nanometer is 1 000 000 (1 million) times smaller than a meter" (False). Furthermore, 24% incorrectly responded to, "The smaller an object is, the smaller its surface area compared to its volume" (False), and 17% to "An animal cell is about 10 nanometers wide" (False). Concerning random movement of nanoscale objects, 31% of respondents erroneously agreed that "Modified nanotubes will move directly towards their intended target after introduced into the body" (False), which indicates anthropomorphicrelated thinking (Höst & Anward, 2017). Furthermore, 19% of respondents were not aware of the fact that "Objects at the nanoscale are kept in random motion by continuous collisions with other particles" (True), which may indicate the conceptual demands of perceiving the "sticky", "shaky" and "bumpy" (Jones et al., 2013) properties of the nanoworld. The result that 56% of participants struggled with the item, "Nanotubes spontaneously aggregate together into rope-like structures" (True), may resonate with a potential lack of (albeit cognitively demanding) knowledge about emergent properties arising from random molecular events. Lastly, when it came to nanoscale interactions, 56% of "Don't know" selections were attributed to, "Attractive forces between objects at the nanoscale become weaker when the contact surfaces of the objects have complementary shapes" (False).

Potential Methodological Limitations

A potential study limitation is designating nanotubes as the prevailing representative "nano-objects" in focus, which captures only one nanomaterial. The sampling strategy used may potentially contain a form of self-selection bias in that 82% of the respondents that chose to participate were either interested or very interested in nano. Nevertheless, analysis did not reveal a skewed distribution towards high levels of nano-knowledge.

CONCLUSIONS

Research on 302 international respondents indicates that NanoKI is a valid and reliable test for measuring a unidimensional factor ascribed to nanoscience and nanotechnology knowledge. Response patterns could frame hypotheses about conceptual challenges around relative size, random motion, and nanoscale interactions.

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