International Journal of Educational Development 62 (2018) 136–147

Contents lists available at ScienceDirect

International Journal of Educational Development

journal homepage: www.elsevier.com/locate/ijedudev

Warning! Increases in interest without enjoyment may not be trend predictive of genuine interest in learning science

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ARTICLE INFO

Keywords:
Affective factors
Environmental education
Genuine interest
Science enjoyment
Scientific competency.

ABSTRACT

Utilizing PISA 2006/2015 datasets for Japan and Taiwan, the multi-group analysis results show significant predictive increases in science interest and scientific competency, and for science interest and environmental awareness; however, revealed significant predictive decreases for science enjoyment and scientific competency, and for science enjoyment and environmental awareness between PISA cycles for both countries. Results signal divergent predictive trends regarding how interest and enjoyment impact students' scientific competency, which may reflect instructional approaches that impede students from experiencing genuine interest in learning science. Why these results should sound an alarm to science and environment educators and policy makers is also forwarded.

1. Introduction

As science-based technologies gain effective dominance in human affairs, it is imperative that every student become both intrigued by and skilled in the more subtle aspects of scientific innovation and reasoning. Becoming knowledgeable about science as human endeavour not only advances a more compelling mindfulness and comprehension of the natural environment but also creates the "reflective citizens" so essential to participation in "personal, local, national and global [cultural] contexts" (Organisation for Economic Co-operation and Development, 2013; Sellar and Lingard, 2014). Collins (1987) posits that "science citizens" are ordinary citizens who possess basic knowledge of "scientific facts" and a "streetwise" understanding of how to apply their knowledge of science to their own lives. This description is synonymous with Feinstein's description of non-science professionals as "competent outsiders" with a personal interest in being engaged "with science" in socially relevant and practical ways (Feinstein et al., 2013). For secondary students to integrate into adult society as competent science citizens, science educators and policy-makers need to be vigilant in monitoring whether science education as currently practiced is capable of making learning science genuinely interesting to these students (Han, 2016). Jack and Lin (2017) posit that genuine interest in learning science is not primarily a question of capturing and focusing the cognitive attention of students on classroom-taught science content. Genuine interest in learning science involves triggering and then maintaining the crucial affective (i.e., emotional) component of enjoyment which, when harmonized with students' cognitive engagement in the classroom, integrates and enhances the science learning experience.

There is growing concern among many practitioners within the science education field about the extent to which students nearing completion of their formal education experience personal interest and enjoyment from acquired scientific competency and environmental awareness in solving issues relating to both the natural and human constructed environments (Jack et al., 2017; Jack and Lin, 2014). With this concern foremost, and under guidance of the OECD, the scientific literacy frameworks for the Programme for International Student Assessments (PISA) 2006 and 2015 focused on affective factors impacting students' scientific competency for meeting a range of real life challenges (Cresswell and Vayssettes, 2006; Jack et al., 2014; Organisation for Economic Co-operation and Development, 2013).

In one recent study, Jack et al. (2016) introduced critical ratio for differences using the PISA 2006 Main Survey (MS) and 2015 Field Trial (FT) datasets to comparatively measure pathway strengths of self-evaluated beliefs (i.e., self-efficacy and self-concept) and direct and general values of science on leisure science engagement among two groups of students sharing common language and culture traditions separated by 8 years of science learning experience. Results suggest encroaching positive and negative trends developing between students' science self-efficacy beliefs impact their leisure science engagement.

Two other recent studies (Lee and Park, 2014; Valenzuela et al., 2015) demonstrate how PISA data can be successfully applied to measure statistical differences among two cohorts to reveal possible trends predicting school practices and student outcomes. However, despite the abundance of results from these and other PISA 2006-related published

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https://doi.org/10.1016/j.ijedudev.2018.03.005
Received 31 July 2017; Received in revised form 30 January 2018; Accepted 20 March 2018

studies, no researchers investigating PISA data cycles have measured and reported statistical differences (1) between two cross-sectional analyses of how science interest and science enjoyment might be predictive of scientific competency; and (2) how these three factors might be similarly predictive of environmental awareness between two groups of students of the same cultural tradition and linguistic backgrounds separated by data collected 9 years apart about science classroom learning experience.

A reoccurring problem reported in studies investigating student's interest in learning science at the science classroom level as well as from narrative reviews of published studies on students' attitudes and interest in learning science is the perpetual stream of students graduating from the education pipeline with a negative impression toward classroom science learning (Jack and Lin, 2014, 2017; Larkin and Jorgensen, 2016; Osborne et al., 2003; Potvin and Hasni, 2014).

Such a negative bias acquired during the formative years of science learning preempts students from positively contributing as citizens to the "science capital" of their country. Archer et al., (2015) defines science capital as

"various types of economic, social and cultural capital that specifically relate to science—notably those which have the potential to generate use or exchange value for individuals or groups to support and enhance their attainment, engagement and/or participation in science" (p. 928).

We agree in part with Archer and her colleagues' assessment that "science-related resources (capital)" have the potential "to actively promote, develop, and sustain their children's science interest." However, we forward that for such science interest to reflect the kind of interest that is internalized into students' current storehouse of acquired interests, they must experience enjoyment and/or satisfaction during their engagement in science learning (e.g., Palmer et al., 2017). Interest without enjoyment results in boredom; however, interest combined with enjoyment results in self-determined engagement and re-engagement (Schukajlow, 2018). We propose that interest combined with enjoyment expresses what Dewey (1903) referred to as "legitimate [i.e., genuine] interest" in learning (p. 11). Genuine interest indicates more accurately the value students place in their acquired science knowledge and skills, and can be applied as human capital to contribute to their own future economic success and social networking opportunities, and as social capital for the future economic success and international networking opportunities of a nation.

This study, therefore, advances current science education literature by extending Jack et al.'s (2016) application of critical ratios by combining, testing, and measuring pathway strength differences among science related-interest, enjoyment, environmental awareness, and science competencies using the PISA 2006 dataset with identical pathways on the PISA 2015 dataset both within Japan and Taiwan. These two East Asia countries share unique similarities in their development and value of science education for promoting economic and industrial modernization (Lin et al., 2016) but differ in their cultural traditions and linguistic backgrounds. The central aim of this study is to determine whether Japanese and Taiwanese students' self-assessed levels of science interest possess the same predictive impact on their scientific competency as their self-assessed levels of science enjoyment. Divergent levels of predictive effects for science interest and science competency, and for science enjoyment and science competency, will signal the prospect that the instructional approaches currently and predominantly used in the science classroom obstruct students from experiencing interest and enjoyment as an integrated whole during instruction.

Comparing these two PISA dataset survey cycle results for Japan and then statistically comparing these results with the PISA dataset survey cycle results for Taiwan will allow us to determine whether differences between pathway strengths can be cross-validated to reveal trends in students' scientific literacy within these two countries. We accomplish this task by designing a four-factor structure equation model (SEM; Fig. 1) which integrates [A] Lin et al.'s (2012) approach for measuring the impact of science related-interest and enjoyment (independent variables) on scientific competency (dependent variable) and [B] Jack et al.'s (2014) approach for measuring the impact of science related-interest and enjoyment (independent variables) to predict environmental awareness (dependent variable) with [C] a new predictive connection for measuring the impact of scientific competency (independent variable) on environmental awareness (dependent variable). This 4-factor model aims to investigate whether formal science education as currently practiced in the classroom supports consideration of affective factors in science and environmental awareness as practical indicators of students' personal attitudes shaping future application of their scientific competencies to science and technological issues as engaged global citizens.

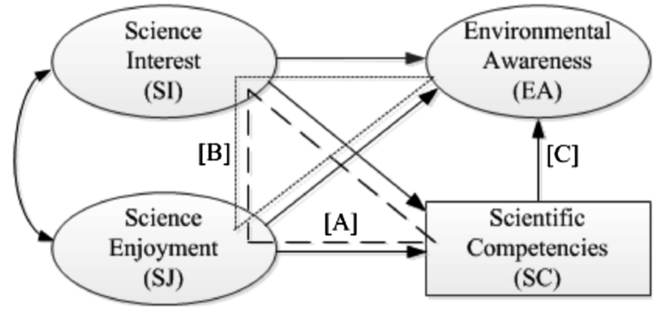

Fig. 1. SEM 4-factor model investigated in this study. Interactions among affective factors and environmental awareness on scientific competency learning outcomes extends approaches made by [A] Lin et al. (2012) and [B] Jack et al. (2014) with a new [C] predictive pathway.

Thus, this current investigation approaches a comparative statistical analysis among two cross-sectional PISA datasets from three investigative fronts: (1) combining science-related interest, enjoyment, scientific competency, and environmental awareness into a 4-factor SEM; (2) applying SEM to the four PISA datasets (Japan PISA 2006 & PISA 2015 datasets; Taiwan PISA 2006 & PISA 2015 datasets) assessing student responses to questionnaire items and scientific competency test items among 4 student populations; and (3) using critical ratio (C.R.) C.R. for differences between pathway estimates to calculate statistical significance of differences within Japan using their PISA 2006 and PISA 2015 datasets, and within Taiwan using their PISA 2006 and PISA 2015 datasets.

Results from this investigation may provide national and international science and environmental educators, policy-makers, and measurement specialists with a consistent and generalizable approach for performing repeated and falsifiable analyses of large-scale PISA data. Such an approach may also prove crucial to revealing practical insights using cross-sectional datasets representing students of the same language and culture tradition regarding how affective factors of interest and enjoyment comparatively connects to levels or degrees of scientific competency and environmental awareness of which few studies have focused.

1.1. Process of analysis and research questions

This study will use a 3-step process of analysis. First, we test the 4-factor model utilizing the Taiwan PISA 2006 dataset to determine and verify any predictive connections among the affective factors of science related interest and enjoyment on environmental awareness and scientific competencies.

Next, we apply the 4-factor model to four different competency assessments using the 2006 and 2015 PISA datasets for Japan and Taiwan. The intent of this repetition is to compare the model fit statistics derived from applying the extended model to each of the assessed PISA datasets, and to cross-validate the model fit statistics derived from