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Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science

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ABSTRACT

Recent research has expanded understanding of the contribution of emotions to student engagement and achievement. Achievement emotions can be conceptualized as general ways of responding to achievement settings or specific emotional states aroused during a specific learning activity. Emotion processes can be distinguished as positive or negative, activating or deactivating. Using data from an international survey of science achievement (PISA 2006; $N > 400{,}000$ 15-year-old students from 57 countries), relations between the positive, activating achievement emotion of enjoyment and a number of variables that combine with enjoyment to define students' engagement with learning science are examined. Previously, we reported that enjoyment is central to relations between interest in science, value and knowledge, and students' reported current and future engagement. The embedded attitudinal items from PISA 2006 allow testing of how enjoyment contributes to a more direct measure of engagement with science by assessing students' interest in finding out more about the specific topics used to measure their science achievement. In this investigation, structural equation modeling is used to test predictions based on Hidi and Renninger's (2006) four-phase model of interest development, and Pekrun's (2006) control-value theory of achievement emotions.

1. Introduction

Concurrent with the upsurge of interest in achievement emotions over the past decade are widespread concerns over students' engagement with core domains of learning such as science and mathematics (Kuenzi, Matthews, & Mangan, 2006). In 2005, the OECD reviewed data that showed declines in the percentages of students studying science, technology, engineering and mathematics (STEM) and recommended that governments take action to make science and technology studies more attractive to students (OECD, 2006b). At the same time a prominent goal of educational policy is that students become lifelong learners (European Commission, 2006). Lifelong learning is seen as involving ongoing, voluntary, and self-motivated learning activities directed to personal or professional development. Directing attention to better understanding of basic processes that make up the complex patterns of behavior that are subsumed by terms such as motivation and engagement hold promise for more constructive ways of designing curriculum and providing educational experiences that expand students' understanding of themselves and their world (Bransford, Brown, & Cocking, 1999; Skinner, Furrer, Marchand, & Kindermann, 2008). Students bring to their learning a legacy of thoughts and feelings associated with earlier learning experiences and this history colors engagement. Achievement emotions are one set of processes accrued from past experiences that students' bring to new achievement tasks and, which when activated by the new task, have the potential to influence task outcomes (Pekrun, Goetz, Titz, & Perry, 2002a). Hence, further investigation of how achievement emotions influence a range of student behavior may deliver important insights to enhance engagement and set the direction for students becoming lifelong learners.

A significant opportunity for investigating the relation between general achievement emotions and adolescent students' intention to engage further with learning experiences is available using data collected in the 2006 international study of science achievement (Programme for International Student Assessment (PISA), OECD, 2007). In PISA 2006 a set of attitudinal variables, including students' enjoyment of science, were included in the student questionnaire. In addition, a special feature of the science knowledge assessment was a series of questions gauging students' interest in learning more about the specific topic content of the science problems they were asked to work on. Therefore, these data provide a strong base for investigating relations between students' enjoyment of science and their interest in finding out more about specific science topics; their expressed intentions for further engagement with learning science.

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In a previous investigation using PISA 2006 science data (Ainley & Ainley, accepted for publication), we examined the structure of relations between major attitudinal variables as defined in PISA 2006, modeling our prediction on features of the four-phase model of interest development proposed by Hidi and Renninger (2006). According to Hidi and Renninger (2006) individual interest in a domain such as science is based on having a knowledge base in science, valuing science and experiencing positive affect when engaged in science activities. Students with an individual interest in science will embrace opportunities to re-engage with science activities, often actively seeking out such opportunities. The attitudinal measures available in PISA 2006 allowed us to test a model of the relation between interest in science and engagement with science activities as measured by two self-report participation variables, one assessing current participation, another, intended future participation. The latter required students to rate their intentions for future participation in science through studies, work and/or science projects (OECD, 2007). We examined the relations between students' science knowledge, personal value of science and enjoyment of science (affect) as they predicted to interest in learning science and from there to current science activities and intentions for future participation. In this model, interest in science was posited to mediate the predictive effects of the knowledge, affect and value components, and the participation variables. This model did not provide a good fit for PISA 2006 data. Some modifications to the model indicated a good fit when the achievement emotion of enjoyment was given a central place in the network linking science knowledge, personal value of science, interest in learning science and the participation variables. In our final model enjoyment of science mediated the relation between personal value of science and interest in learning science. Enjoyment of science also mediated the relation between the personal value of science and the two participation variables (Ainley & Ainley, accepted for publication). Hence, our conclusion that enjoyment of science was central to the prediction of students' participation in science activities.

In the current investigation we focus on the relation between enjoyment of science, interest in learning science, and another participation or engagement variable, more specifically, students' expressed interest in learning more about a series of specific science topics. This measure represents a different perspective on engagement to the measures used in the previous study. The major assessment of science achievement in PISA 2006 was based on problems that emphasize understanding and application of knowledge in real-life situations. For a number of these problems, when students finished working on the problem they reported how interested they were in learning more about that topic. These items are referred to as embedded interest items[1] and referred to the specific science content the student had been working on. For example, one of the problem scenarios was on the topic tobacco smoking and, at the end of the problem questions, students were asked how interested they were to know more about the effects of smoking on the body (OECD, 2006a, p. 146). Hence, this measure has an immediacy which is not generally the case when students generate their own context or frame of reference to respond about their interest in learning science. Following our findings concerning the central role of enjoyment of science in our earlier modeling of interest in science from PISA 2006 (Ainley & Ainley, accepted for publication), in the current investigation we focused on exploring the relation between enjoyment of science, interest in learning science, and students' expressed interest in reengaging with the specific science topics.

Two issues are central to the model we are exploring. The first concerns the relation between enjoyment of science and interest in science and the second concerns the relation between personal value of science and students' enjoyment of science.

2. Enjoyment and interest: separate and complementary emotion constructs

So what is the relation between enjoyment and interest, and what do we expect to find when enjoyment of science is measured at the level of the students' general response to learning science, and interest in science is measured as an expressed desire to maintain engagement with specific topics and acquire further knowledge and understanding?

In order to understand these relations first we consider some perspectives on the relation between enjoyment and interest. Recent writings from the positive psychology group (e.g., Fredrickson, 2001; Seligman & Csikszentmihalyi, 2000) have focused attention on the role of positive emotions in human behavior and in their writings relations between enjoyment and interest are explored. For example, Fredrickson (2001) and Fredrickson and Branigan (2005) differentiate between positive emotions, and among the specific positive emotions are joy and interest. Whereas negative emotions narrow the individual's focus in preparation for defensive action, Fredrickson emphasizes that the function of positive emotions is more likely to be one of expanding an individual's focus and refers to the function of positive emotion as "broaden-and-build". Fredrickson uses the term joy rather than enjoyment and suggests that emotions such as joy and interest have complementary effects, the playfulness of the emotion joy combines with the exploratory and information seeking of the emotion interest. A similar perspective on the co-occurrence of interest and enjoyment is represented in Izard's (2007) proposition that the emotion interest is involved in a wide range of complex human behavior. He argues that alongside the interest expressed in attention to situations that are novel, ambiguous or uncertain, the information that is being processed generates other emotions consistent with the character of the situation. Constructive, creative activities are associated with interest, joy and contentment combinations.

This linking of enjoyment and interest is not new and can be seen in Rathunde and Csikszentmihalyi's (1993) concept of undivided interest which, following Dewey (1933), was defined as "serious play". According to Dewey, conditions for learning are maximized when an activity is both playful and serious. The essential condition for learning is that enjoyment and the focused attention of interest are both generated in response to the learning activity. When the enjoyment in a learning activity is not connected with the informational content, students soon lose interest and disengage. This has been shown very starkly in studies in the 1980s and 1990s when learning activities were delivered via the medium of new electronic computers. Many students were found to disengage once the initial novelty of the medium had passed (e.g., Cordova & Lepper, 1996; Lepper & Gurtner, 1989).

Hence, from this perspective the combination of joy and interest can be expected to be associated in achievement settings with high levels of task engagement. Students who experience joy and interest while working on a science topic are engaged with the topic content and are likely to express a desire to continue their engagement with the topic.

To this point we have been referring to emotions of enjoyment and interest as they occur in response to the immediate situation, with particular reference to achievement contexts. However, a substantial amount of the current research into achievement emotions involves measurement at a more general level. Students are asked to report how they generally feel in relation to learning science, or in relation to their mathematics classes (e.g., Pekrun, 2006; Pekrun et al., 2002a). Most of the consideration of enjoyment as an achieve-

[1] A second form of embedded item was concerned with students' support for scientific enquiry and is not part of the analysis in this paper.

ment emotion has been at this general level although there are some research findings which have focused on the state (e.g., Ainley, Corrigan, & Richardson, 2005; Goetz, Frenzel, Pekrun, & Hall, 2006).

Research into the role of interest in educational achievement commonly distinguishes between situational interest where the interest is specific to the immediate situation and may be transient, and individual interest which represents a more enduring pre-disposition to re-engage with the content of the interest activity or domain. More recently this basic distinction has been developed into taxonomies describing phases or stages of development of interest from situational to individual (see Hidi & Renninger, 2006; Krapp, 2003). Hidi and Renninger (2006) distinguish two phases within situational interest. The first phase is a newly triggered situational interest which is a transient state consisting of positive affect and focused attention. In the second phase, maintained situational interest, this state continues for a relatively longer period of time. The affect and attention are sustained through the meaningfulness or personal value of the task. Distinguishing the more developed phases of individual interest, Hidi and Renninger (2006) suggest that over time a maintained situational interest can accrue knowledge and value components to the extent that the student now expresses a more extended commitment to the domain (an emerging individual interest) and seeks to re-engage and extend their contact with the domain. The final phase, a well-developed interest, represents a personal orientation or predisposition to engage and re-engage with the domain and consists of an organization of affect, accrued knowledge and value.

A similar model has been proposed by Krapp (2003) distinguishing three stages in the development of an interest:

> "a situational interest awakened or triggered by external stimuli for the first time; a 'stabilized situational interest' which lasts over a relatively more extended time; and the third stage which is the individual interest identified as a relatively enduring predisposition to engage with an object-area or domain" (p. 69).

The central elements across these stages adhere in both affective and value components. Interest consists of a relation between person and object defined by a combination of emotion and value. Unlike Hidi and Renninger's (2006) model, this model does not give a central place to knowledge components in the structure of an individual interest.

Both models of interest development (Hidi & Renninger, 2006; Krapp, 2003) refer to students' responses to specific content although the breadth of the content can vary. While often referring to major schooling domains such as mathematics and science, the content that provides the referent for interest may be something more restricted such as, for example, the habitat of southern whales, or music styles of the Middle Ages. In addition, when referring to an individual interest the positive affect may involve emotions other than enjoyment and also may include negative emotions in response to specific content features (Ainley et al., 2005; Hidi, 2006).

At a more general level, Hunter and Csikszentmihalyi (2003) have explored the construct of chronic interest as a broad orientation to experience among adolescents. This construct is informative for the current discussion because the measure of chronic interest is a composite of affective states. One end of the dimension describes adolescents "who experience stimulation, enthusiasm, and pleasure and on the other adolescents who are perpetually in a disconnected state of apathy" (p. 30). The positive end of the scale includes adolescents whose responses to new experience involve attention, focus, and enjoyment; again the co-occurrence of enjoyment and interest is central.

What comes through these different perspectives is that there is an association between enjoyment and interest, either at a state level or a more generalized level that functions to engage the individual with experience. Across a range of research, enjoyment and interest emerge as separate emotion constructs but with complementary functions in relation to exploring new objects and situations, and to acquiring new knowledge and experience. For schooling domains we would expect to find interest and enjoyment occurring together both at the level of immediate response and when monitoring how students generally feel. Therefore, with the attitudinal and embedded measures from PISA 2006 we would expect to find a close association between general enjoyment of science and interest in learning science, and that both would be predictive of students' interests in learning about specific topics.

3. Personal value and enjoyment

In keeping with the close association between the achievement emotion of enjoyment and the forms of interest that have been described above, it is not surprising that perspectives on enjoyment and on interest include a role for personal value. Both of the models of interest development we have described give a central place to personal value in the development of individual interest and this has been supported in recent empirical research (Durik & Harackiewicz, 2007; Harackiewicz, Barron, Tauer, & Carter, 2000). In the current investigation the individual interest variable was students' interest in learning science which on the one hand is expected to predict to students' interest in learning more about specific topics (embedded interest), and on the other hand is expected to be predicted by personal value of science. Our previous investigation using PISA 2006 data (Ainley & Ainley, accepted for publication), indicated that personal value of science was predictive of interest in learning science but that most of the effect was mediated through enjoyment of science. Therefore, in the current model we examined whether this pattern also applied for interest in learning about specific science topics (embedded interest).

The relation between personal value of science and enjoyment of science also requires some examination. Pekrun's (2006) control-value theory of achievement emotions proposes that value is one of the key predictors of enjoyment. Some detail of the control-value theory is required to explain the relation we expect to find between personal value of science,[2] enjoyment of science and students' interest in learning more about specific science topics (embedded interest).

The control-value theory of achievement emotions presents a taxonomy organized in terms of three dimensions; valence (positive versus negative), activation (activating versus deactivating) and object focus (activity versus outcome). Enjoyment is classified as a positive, activating, activity focus emotion and involves thoughts and cognitions concerning the process of working on an achievement activity. Hence, enjoyment involves experiencing pleasure in an activity. In the development of the taxonomy (see Pekrun, Goetz, Titz, & Perry, 2002b) task-related positive emotions are distinguished as process (i.e. activity): enjoyment; prospective: anticipatory joy; and retrospective (i.e. outcome): joy about success. Using this taxonomy, achievement emotions can be measured at a range of levels of generality. At the most specific level measures are in relation to a particular activity, at a more general level to a set of activities, and at the broadest level to a domain. In PISA 2006 the enjoyment of science variable referred to students' general level of response to the activities involved in learning science.

Control-value theory (Pekrun et al., 2002a) predicts that learning situations with high personal value will be positively related to students' experience of enjoyment in achievement contexts. Within personal value a distinction is made between two forms of value. Achievement value represents beliefs about the value of achievement outcomes. For example, a student with high achieve-

[2] The control component of the control-value theory is not included in modeling presented here.

ment value in science believes that achieving high grades in science is important for them. On the other hand, domain value represents beliefs concerning the intrinsic value of the domain and is operating when a student believes that learning science helps understand things about their life. According to control-value theory high domain value will trigger enjoyment as well as other positive achievement emotions such as pride. In PISA 2006, the personal value of science item content expressed beliefs about the value of science in terms of domain value, that is, students understanding things around them, both now and in the future. Consistent with what was established in the previous investigation (Ainley & Ainley, accepted for publiction), it was expected that personal value of science would be a strong predictor of students' enjoyment of science, and that enjoyment would mediate its predictive effects on interest in learning science. The significant contribution for the present investigation is to determine how the effect of personal value on enjoyment of science and interest in learning science, predicted to the more specific indicator of students' intention to engage further with specific science topics as represented in the embedded interest items.

4. Some cross-national comparisons

The PISA 2006 survey provides an opportunity to test whether the patterns of association linking interest in science variables are the same for students from countries with different historical and cultural traditions. According to Bronfenbrenner's (1992) ecological model for understanding human development, identifying countries on the basis of their historical and cultural traditions involves applying a macrosystem perspective. One appropriate framework for distinguishing countries by macrosystem factors is the two dimensional values structure which Ingelhart and colleagues (Inglehart & Baker, 2000; Inglehart & Welzel, 2005) have developed using data from the World Values Surveys and European Surveys (1981–1982; 1990–1991; 1995–1998). According to Inglehart and colleagues two orthogonal value factors underlie the patterns of responses to these value surveys. The first dimension consists of an orientation to authority. This dimension contrasts more traditional values emphasizing religion and obedience to traditional authorities, with secular-rational values where family and social values are viewed as relative rather than absolute and where deference to religious authority is not a high priority. The second dimension contrasts survival values where the physical and economic security of the community is central to values, with self-expression and values such as subjective well-being, individual autonomy and personal quality of life being prominent concerns.

Not all of the countries participating in PISA 2006 are represented on the world culture map and so four countries represented in the World Values Surveys and who also participated in PISA 2006 were chosen to represent the most extreme position available for each of the four quadrants defined by the intersection of these two dimensions. Colombia was chosen to represent the traditional/survival (T–S) values. It should be noted that there were very few countries participating in PISA 2006 who were towards the extreme on the survival values dimension. Colombia was closer to the middle of the survival/self expression dimension but was towards the extreme of the traditional values axis. The United States was selected for the traditional/self expression (T–SE) quadrant, Estonia for the secular-rational/survival (SR–S) quadrant and Sweden for the secular-rational/Self Expression (SR–SE) quadrant. These four countries with different historical and cultural traditions were chosen to examine whether the pattern of relations in our model fit across a range of countries.

Country selection was based on a consideration of macrosystem perspectives. At the same time it is well documented that socio-economic factors are associated with academic achievement. In PISA 2006 students from more advantaged socio-economic backgrounds gained significantly higher scores on measures of science literacy than students from less advantaged backgrounds. This was true in all countries although there was considerable variation among countries in the strength of that association (see OECD, 2007, p. 183ff). PISA 2006 used an index of economic, social and cultural status (ESCS) which combined information provided by students about their father's and mother's occupations (scaled to reflect status) and level of education with an index of home possessions including family wealth (e.g., whether students had room of their own, internet access), access to educational resources (e.g., quiet place to study, books to help with their schoolwork), and cultural possessions. This index of economic, social and cultural status represents family environment factors, or the microsystem influences on students' interest and achievement in science, and for that reason ESCS has been included in our model of science enjoyment and interest.

In summary, using countries with different cultural and historical traditions as identified by Inglehart (Inglehart & Baker, 2000; Inglehart & Welzel, 2005), the aim of the current investigation was to determine the significance of students' knowledge of science and personal value of science, as predictors of their enjoyment of science and their interest in learning science, and how they in turn predicted to topic specific indicators of students' intention to engage further with science content.

5. Method

5.1. Samples

The Programme for International Student Assessment (PISA) is an international survey of achievement among nationally representative samples of 15-year-old students across OECD and partner countries. These surveys are conducted every 3 years and each survey has a major focus on one of three domains, reading, mathematics or science. PISA 2006, the data set used in the current investigation, focused on science. In 2006 more than 400,000 students from 57 countries participated in the survey. Within each country schools and students were selected in a two-stage sampling design (schools with a probability proportional to size and students at random within schools) (OECD, 2007, pp. 347–359). For each of the countries in our investigation the analysis is based on samples of more than 4000 students: Colombia $N = 4412$, United States $N = 5444$, Estonia $N = 4837$, and Sweden $N = 4351$. These samples included approximately equal numbers of girls and boys.

5.2. Procedure and measures

In their schools participating students completed an assessment of science knowledge and understanding that took approximately 2 h (OECD, 2007, p. 19). Each student answered questions in one of 13 randomly assigned booklets (based on combinations of four item clusters in a rotated block design). This procedure ensured comprehensive coverage (the total time for all four clusters would have been 210 min) of the science content domain (OECD, 2009, pp. 28–29). There were 31 topic specific embedded interest items in the item clusters and each followed immediately the set of achievement items on the relevant topic. Scores for science knowledge and scores for the embedded interest items are based on students' responses to this assessment. In addition, after they completed this assessment, students completed a 30 min questionnaire made up of items dealing with family background, access to educational resources and a range of attitudinal measures including personal value of science, enjoyment of science, and interest in learning science.

5.3. Establishing cross-national validity

Cross-national validity is an important issue in large-scale international surveys such as PISA. The processes of development, piloting, field trial and main survey analysis are directed towards establishing measurement equivalence across countries. Instruments were designed, in association with a series of international expert groups (in this case the questionnaire expert group, the science expert group, and the technical advisory group), by teams from institutions from countries and reviewed by national project managers from every participating country (see OECD, 2009, pp. 35–38). This included a process of national and international piloting followed by a field trial in every country. Field trial, and main survey, data were analysed within each country to examine the dimensionality of the scales and item fit to the measurement model as well as identifying differential item functioning (DIF) among countries. At the field trial level any items that functioned differently across countries were eliminated (see OECD, 2009, pp. 318–327 and 351–365). In addition correlations among attitudinal scales and between each attitudinal scale and other variables were examined for each country (see OECD, 2009, pp. 357–364).

5.3.1. Science knowledge (SCK)

The PISA 2006 survey measures reading, mathematical and science literacy. The use of the term literacy reflects the PISA emphasis on understanding, and the application of knowledge, in real-life situations. The assessments are based on questions set in context-rich scenarios. Science knowledge encompasses knowledge of science and knowledge about science and was based on four content areas elaborated in the assessment framework: physical systems, living systems, earth and space systems and technology systems (OECD, 2006a). The assessment included 103 items of both multiple-choice and constructed response formats. Scores on the science assessment were derived from item response theory methods (specifically the Rasch model) with the scores transformed to a scale with a mean for OECD countries of 500 (and a standard deviation of 100).[3] The science knowledge scale is highly reliable (see OECD 2009, p. 215) with a reliability coefficient of 0.86 for the plausible values. For the four target countries the respective coefficients were 0.87 for Colombia, 0.93 for United States, 0.91 for Estonia, and 0.92 for Sweden (OECD, 2009, p. 217).

5.3.2. Embedded interest (EIS)

Embedded within the instrument assessing science knowledge, and linked to the content that formed the basis of the knowledge assessment, there was a series of items designed to measure two attitudinal dimensions. One set consisted of questions concerning students' interest in finding out more about the problem topic and the other set was concerned with students' support for scientific enquiry. It is the embedded interest items which are of concern in this investigation. The stem for the embedded interest items asked "How much interest do you have in the following information?" Each of the specific topic information items commenced with a phrase such as "knowing more about", "learning more about", or "understanding better". Response options were recorded using a four point scale from *High interest*, through *Medium interest* and *Low interest* to *No interest.* For example, the content of one of the problem topics concerned tobacco smoking. At the end of the problem questions students were asked "How much interest do you have in the following information?" Students were given three statements: "Knowing how tar in tobacco reduces lung efficiency", "Understanding why nicotine is addictive", and, "Learning how the body recovers after stopping smoking" (OECD, 2006a, p. 146). Responses to these items were subjected to a series of psychometric analyses to determine their validity (see OECD, 2009) and to construct embedded interest and embedded support scales.[4] Rasch analysis methods were used to derive scores on the embedded interest scale and the scale score was transformed so that the overall mean for OECD countries was 500 and the standard deviation was 100. The overall reliability for this scale as reported in the scale construction was 0.89 (OECD, 2009, p. 355). For the four target countries the respective coefficients were 0.83 for Colombia, 0.91 for United States, 0.87 for Estonia, and 0.90 for Sweden (OECD, 2009, p. 217). This embedded interest scale was used in the current investigation as an expression of students' desire to engage further with the problem topics.

5.3.3. Socio-economic status (SES)

The PISA 2006 index of economic, social and cultural status (ESCS) has a mean of 0.0 and a standard deviation of 1.0 for OECD countries. The mean ESCS scores for the four target countries were: −0.93 for Colombia, 0.13 for the United States, 0.18 for Estonia, and 0.23 for Sweden.

5.3.4. Personal value of science (PVS)

Personal value of science was measured using five items expressing ways that science had personal value for the respondent and the response options were labeled *Strongly agree, Agree, Disagree,* and *Strongly disagree*. Example items are "I find that science helps me to understand things around me" and "I will use science in many ways when I am an adult". The scale scores are weighted likelihood estimates (wle) in which the mean for OECD countries is 0.0 and the standard deviation is 1.0. For the four target countries the respective reliability coefficients were 0.71 for Colombia, 0.84 for United States, 0.74 for Estonia, and 0.85 for Sweden (OECD, 2009, p. 326).

5.3.5. Enjoyment of science (ENJ)

Five items based on the enjoyment scale from the Achievement Emotions Questionnaire (AEQ; Pekrun, Goetz, & Perry, 2005) were used to measure enjoyment of science. Example items are "I generally have fun when I am learning <broad science>[5] topics" and "I am happy doing <broad science> problems" and the response options were labeled *Strongly agree*, *Agree*, *Disagree*, and *Strongly disagree*. The scale scores are weighted likelihood estimates (wle) in which the mean for OECD countries is 0.0 and the standard deviation is 1.0. The scale had strong reliability coefficients and for the four target countries the respective coefficients were 0.85 for Colombia, 0.93 for United States, 0.87 for Estonia, and 0.95 for Sweden (OECD, 2009, p. 320).

5.3.6. Interest in learning science (INS)

The measure of interest in learning science asked participants "How much interest do you have in learning about the following <broad science> topics?" The four response options were labeled *High interest*, *Medium interest*, *Low interest*, and *No interest*. The list of topics included physics, chemistry, biology of plants, human biology, astronomy, geology and two aspects of the scientific approach to knowledge, namely, "ways scientists design experiments" and "what is required for scientific explanations". The

[3] To account for the measurement error associated with the rotated booklet assessment design a set of five plausible values for the science knowledge scale is reported but in this paper the first of the plausible values is used as the basis for the analysis.

[4] Embedded support for science is not included in the analyses for this investigation.

[5] From the questionnaire: "<broad science> refers to any topics that you might encounter in school or outside of school (for example on television) that relate to space science, biology, chemistry, Earth science or physics." (Student Questionnaire for PISA 2006, p. 11 //mypisa.acer.edu.au).

scale scores are weighted likelihood estimates (wle) in which the mean for OECD countries is 0.0 and the standard deviation is 1.0. For the four target countries the respective coefficients were 0.78 for Colombia, 0.87 for United States, 0.75 for Estonia, and 0.88 for Sweden (OECD, 2009, p. 320).

5.4. Analysis

Following the results of our previous analysis where personal value of science and science knowledge were predictors of enjoyment of science which in turn predicted to interest in learning science and the two participation variables, we tested the same model but with embedded interest as the outcome variable. In addition, socio-economic status was included to statistically allow for its significant positive relation with science knowledge. Thus, our model envisaged that socioeconomic background influenced science knowledge and personal value of science and these potentially influenced enjoyment of science, interest in science, and interest in specific science topics (embedded interest).

We used structural equation modeling (AMOS 17.0) (see Arbuckle, 2005) to test the fit of our path model and estimate the strength of the relationships among its constituent elements. The model was run separately for all four countries. Although PISA data are based on clustered samples, the intra-class correlation coefficients for the interest and attitudinal measures that are the focus of this paper are low (OECD, 2007, pp. 18–19). For embedded interest in science the values of the within-country intra-class correlation coefficients for the four countries in this paper were 0.04 (Colombia), 0.05 (United States), 0.05 (Estonia) and 0.04 (Sweden). The corresponding average within-country intra-class correlation coefficients for the four countries in this paper were 0.06 for interest in science, 0.07 for enjoyment of science, and 0.06 for personal value of science.[6] For this reason we used single-level (student level) analysis.

The model was run separately for all four countries. Science knowledge and personal value of science were entered as predictors of enjoyment of science. Science knowledge, personal value of science and enjoyment of science were entered as predictors of interest in learning science. The final set of paths entered consisted of science knowledge, personal value of science, enjoyment of science and interest in learning science as predictors of embedded interest in science and is shown in Fig. 1.

6. Results

The descriptive statistics and correlations between each of the variables for each of the four countries are presented in Table 1.

Mean scores for enjoyment, personal value and interest in science were above the PISA average for Colombia and below the PISA average for Sweden. Science knowledge scores varied between the four countries. The average for Colombia was more than one standard deviation below the overall mean and the United States approximately half a standard deviation below the overall mean. The average for Sweden was close to the overall mean while Estonian students scored approximately one third of a standard deviation above the overall mean. Correlations across the set of variables differed across the four countries. For Colombia the correlation between science knowledge and the other scales was very small and negative. For the other three countries the correlation coefficients with knowledge were all positive with Sweden generally having the strongest correlations with science knowledge. For all of the

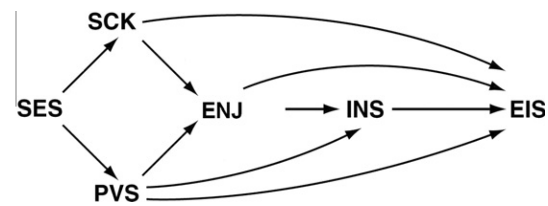

Fig. 1. Model of relations between predictors of embedded interest.

countries except Sweden the correlation between science knowledge and embedded interest was close to zero. For Colombia and Estonia these correlations were positive while for the United States the correlation between knowledge and embedded interest was negative. In contrast, the correlation between knowledge and embedded interest for Sweden was stronger (.22) and also positive.

The correlations between personal value of science, enjoyment of science, interest in learning science and embedded interest are central to the predictive relations that we are testing. For all four countries there were strong correlations between personal value of science, enjoyment of science and interest in science and between these variables and the embedded interest scores.

Each country in the analysis had a relatively large sample of participants (more than 4000 students from at least 150 schools). The main test of fit considered was the root mean square error of approximation (RMSEA). Values of .05 and less indicate a close fit; values up to .08 represent an acceptable fit and values greater than .10 indicate a poor model fit (Byrne, 2001). Other indices of model fit that are considered to be relatively independent of sample size and correct for model complexity were also considered. High values (greater than 0.9) for CFI and TLI indicate satisfactory model fit. In Table 2, these and several other fit indexes are shown along with the standardized parameter estimates. Because our sample sizes are so large the chi-square statistic testing the fit against the null hypothesis provides a poor measure of fit. The fit indices and standardized parameter estimates for all four countries are shown in Table 2. The correlation between science knowledge and personal value of science (see Table 1) were included when the model was estimated.

The RMSEA results indicate a close fit for the Estonia and Sweden data sets and an acceptable fit for the Colombia and United States data sets. All other fit indices are greater than 0.9 confirming a satisfactory model fit for all four countries. Table 2 also reports the standardized parameter estimates. The model fit statistics indicate that although the model has an acceptable fit for all four countries, the strength of the predictive paths varied. For all four countries the strongest paths in the model (bolded) show a path connecting personal value of science with embedded interest in science mediated through enjoyment of science and interest in learning science. These paths are strongest for Sweden and weakest for Colombia.

Taking the main paths in the model separately it is clear that personal value of science has a strong positive relation with enjoyment of science and this was true for all four countries with the lowest parameter estimate being .54 for both Colombia and Estonia. While the correlations between personal value and interest in science were substantial (see Table 1), the parameter estimates between personal value of science and interest in science are relatively low indicating that the predictive relation between personal value and interest in science is partially mediated through enjoyment of science. In turn the relation between enjoyment of science and embedded interest is largely mediated through the strong positive relation between interest in learning science and embedded interest. It should be noted that these are not fully mediated effects. In sum, the strongest path in the model links personal value with enjoyment which in turn is linked to embedded interest through interest in learning science.

[6] For all countries the international averages for the within-country intra-class correlation coefficients were 0.11 for each of interest in science and enjoyment of science, and 0.09 for personal value of science.

Table 1
Descriptives and correlations between scales used to test model of relation between enjoyment and embedded interest for Colombia, United States, Estonia and Sweden.

	Mean[a]	*SD*	SES	ENJ	PVS	INS	SCK	EIS
Colombia ($N = 4412$)								
SES	−.93	1.24	–	−.05	−.05	−.11	.36	−.05
Enjoyment (ENJ)	.80	0.78		–	.54	.43	−.05	.31
Personal Value (PVS)	.88	0.84			–	.41	−.07	.35
Interest (INS)	1.12	0.94				–	−.08	.40
Knowledge (SCK)	391.53	85.14					–	.05
Embedded interest (EIS)	642.47	104.12						–
United States ($N = 5444$)								
SES	.13	0.91	–	.15	.18	.08	.42	−.06
Enjoyment (ENJ)	−.04	1.01		–	.60	.63	.28	.46
Personal value (PVS)	.29	1.04			–	.54	.24	.42
Interest (INS)	.02	1.08				–	.14	.55
Knowledge (SCK)	488.29	105.57					–	−.06
Embedded interest (EIS)	479.79	104.75						–
Estonia ($N = 4837$)								
SES	.18	0.80	–	.12	.14	.14	.31	.05
Enjoyment (ENJ)	.02	0.85		–	.56	.54	.22	.51
Personal value (PVS)	.15	0.84			–	.48	.20	.47
Interest (INS)	.20	0.75				–	.16	.59
Knowledge (SCK)	534.50	83.53					–	.03
Embedded interest (EIS)	503.51	75.55						–
Sweden ($N = 4351$)								
SES	.23	0.78	–	.20	.22	.19	.34	.13
Enjoyment (ENJ)	−.09	1.04		–	.69	.69	.37	.57
Personal value (PVS)	−.10	1.01			–	.59	.29	.51
Interest (INS)	−.11	1.04				–	.32	.64
Knowledge (SCK)	504.27	94.03					–	.22
Embedded interest (EIS)	455.49	90.07						–

[a] SES, ENJ, PVS, INS, overall mean for OECD countries = 0.0, *SD* = 1.0; SCK, EIS overall mean for OECD countries = 500.0, *SD* = 100. Note: SES = socio-economic status; ENJ = enjoyment of science; PVS = personal value of science; INS = general interest in learning science; SCK = science knowledge; EIS = embedded interest in science.

Table 2
Enjoyment and embedded interest model: fit indices for Colombia, Unites States, Estonia, and Sweden.

		Colombia (T/S)	USA (T/SE)	Estonia (SR/S)	Sweden (SR/SE)
Knowledge (SCK)	← SES	.36	.42	.31	.34
Personal (PVS)	← SES	−.06	.17	.14	.22
Enjoyment (ENJ)	← Knowledge (SCK)	$-.01_{ns}$	.15	.11	.19
Enjoyment (ENJ)	**← Personal (PVS)**	**.54**	**.57**	**.54**	**.64**
Interest (INS)	← Personal (PVS)	.25	.26	.25	.21
Interest (INS))	**← Enjoyment (ENJ)**	**.29**	**.48**	**.40**	**.55**
Embedded interest (EIS)	**← Interest (INS)**	**.29**	**.39**	**.41**	**.44**
Embedded interest (EIS)	← Personal (PVS)	.19	.14	.18	.13
Embedded interest (EIS)	← Enjoyment (ENJ)	.09	.19	.21	.20
Embedded interest (EIS)	← Knowledge (SCK)	.09	−.20	−.12	−.04
	NFI	.988	.991	.995	.996
	RFI	.940	.954	.976	.981
	IFI	.989	.992	.996	.997
	TLI	.944	.956	.978	.983
	CFI	.989	.992	.996	.997
	RMSEA	.051	.061	.039	.043
R^2	Enjoyment (ENJ)	.29	.38	.33	.51
	Interest (INS)	.23	.44	.34	.51
	Embedded interest (EIS)	.22	.36	.43	.46

Note: the variables and coefficients for the strongest paths in the model are shown in bold.

The strength of this path from personal value through enjoyment of science and interest in learning science to embedded interest can be seen in the size of the squared multiple correlation coefficients. The model explains between 22 (Colombia) and 46 (Sweden) per cent of the variance in embedded interest scores while the squared multiple correlation coefficients for the mediators of general interest in science ranged from 23 (Colombia) to 51 (Sweden) per cent, and enjoyment ranged from 29 (Colombia) to 51 (Sweden) per cent.

The parameter estimates within the model that involve science knowledge are also informative and here there was some variation between the models for the four countries. When the relatively strong relation between science knowledge and socio-economic status was statistically controlled, the parameter estimates linking knowledge and enjoyment were significant for Estonia, Sweden and the United States, but not for Colombia. In addition, when allowance was made for the effects of science knowledge on enjoyment there was a negative effect of science knowledge on embedded interest for United States, Estonia and Sweden. For the United States this parameter estimate is relatively large (−.20) and requires some interpretation.

The embedded interest items were recorded as soon as students had completed the set of questions concerned with a specific problem scenario. They were asked to respond to items specifying the topic of the scenario they had been working on and asking how interested they were in learning more about; acquiring more knowledge about; and understanding more about that topic. There are a number of possible interpretations of high ratings for these questions. One is that students gave a high rating of interest when they felt they had not done well on the questions and should learn something about the topic. A high rating of interest is a response to performing poorly. This interpretation is consistent with negative parameter estimates between knowledge and embedded interest. The size of the negative parameter estimates varied considerably the highest being for the United States.

A second possible interpretation is that a high rating of interest indicates that while working through the problems students became aware of some previously unexperienced personal relevance, uncertainties or novelty in the topic and wanted to know more than was covered in the problems. This type of response equally could be from a student who had a mediocre performance or a student who had performed well on the problems. This is the response that is typical of someone who has had their interest aroused. On the basis of the size of the parameter estimate for this path in the Swedish sample, students giving high ratings on the embedded interest questions were likely to have some personal interest in science rather that this being the triggering of a new interest. The same interpretation is relevant for the other three countries where interest in science was a smaller but still substantial predictor of embedded interest.

7. Discussion

The findings from these analyses suggest that there are strong predictive relations between personal value of science, enjoyment of science, interest in learning science and students' interest in learning more about specific science topics measured as embedded interest. The evidence of these relationships lends support to the main propositions that informed the development of the model.

Enjoyment and interest were very closely associated. Interest in learning about science mediated the effect of enjoyment of science on embedded interest, that is, students' expression of their desire to engage further with topics they had been working on. The embedded interest items focused on wanting to engage further with aspects of content; to follow up the topic and acquire further knowledge and understanding. Hence, the predictive relation with enjoyment is pointing to the likelihood that students who gave high ratings on these embedded interest items were also likely to have experienced enjoyment as they worked through the questions. These results suggest that an important aspect of students' engagement with science topics is the mix of enjoyment and extending knowledge and understanding through the focused attention characteristic of interest, or in Dewey's (1933) terms, serious play. Students' general enjoyment of science and general interest in learning science have developed out of their previous experiences learning science and function in new situations as expectations or predictions about further science experiences. Therefore, these results point to the importance of both early experiences with science and the maintenance of a sense of fun and excitement while learning science.

What is particularly significant about these findings is that the measures are at different levels of specificity. Both enjoyment of science and interest in learning science were measured as the way students generally feel about science. On the other hand the embedded interest measure referred to reactions to a specific topic that was in the forefront of the students' attention. Therefore, the measure of embedded interest has an immediacy which is not generally the case when students generate their own context or frame of reference to respond about their general or usual level of interest in learning science. One implication of these findings for further research on achievement emotions is that measurement strategies and research designs that target students' immediate experience provide complementary perspectives to the more common general level of measurement. As can be seen in our results, the measurement of target variables at both the general and the more specific levels has given broader insight into the specific processes involved in student engagement with science than either level of measurement alone.

While enjoyment and interest are important experiences that influence students' engagement and re-engagement with the content of science topics, the importance of personal value of science and students' engagement should not be overlooked. According to the model that was supported in this investigation when students believe that the topics they are dealing with in science have personal relevance and meaning for their lives they are more likely to experience enjoyment and interest from engaging with science content. How often do students see their science curriculum as being about understanding their physical world, their biological world and their interactions within their physical and social contexts? According to the findings from this investigation personal meaning and relevance is an important factor in students' enjoying science and focusing their attention to expand their knowledge and understanding. Working together these factors are associated with higher levels of expressed intention to engage further with science content and as has been shown in longitudinal studies of students' intentions for further participation (Khoo & Ainley, 2005), intentions are an important predictor of actual participation.

However, these findings are not without limitations. The model we tested with these data achieved an acceptable fit. There may be other models that also achieve an acceptable fit. Evidence from other types of investigations is needed to confirm these patterns and to test their application. We have chosen four countries for investigation on the basis of findings concerning their contrasting historical and cultural traditions. There are other bases for describing differences between the educational environments of students in OECD and partner countries. Our findings will be enriched by applying this model to other sets of countries chosen because they represent specific educational environments. In addition, we have not explored whether there are gender effects within the relations between these variables. Calculation of gender differential item functioning (DIF) indices for the embedded interest items indicated that a number of the embedded interest items had DIF values larger than the critical .3 (OECD, 2009, p. 357). Examination of the educational significance of these differences in the bases of male and female students' interest in finding out more about specific science topics requires a more detailed analysis of the nature and origins of gender differences in response to learning about science than is possible in this paper.

The upsurge of research interest in the role of achievement emotions and the range of research that is currently being undertaken when considered alongside results from large international surveys will provide broader perspectives on the psychological processes, including achievement emotions, that are active when students around the world engage with science content and so provide the important "hints to be interpreted" (Scheerens, 2009) by educational practitioners.

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