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Disentangling intensity from breadth of science interest: What predicts learning behaviors?

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Abstract Overall interest in science has been argued to drive learner participation and engagement. However, there are other important aspects of interest such as breadth of interest within a science domain (e.g., biology, earth science). We demonstrate that intensity of science interest is separable from topic breadth using surveys from a sample of 600 middle school students. We also show that these two dimensions contribute differently to learning-relevant behavioral tendencies. Specially, regression analyses show: (1) that intensity of interest predicts both self-reported science classroom engagement and preferences to participate in optional science learning; and (2) that breadth of interest predicts science choice preference, but not science classroom engagement. These findings have implications for the conceptualization of interest, the measurement of interest, and practical applications for educators.

Keywords Science interest · Topic interest · Middle school

Introduction

Research has extensively examined the foundational role interest can play in adolescents' persistence, engagement, and achievement in domains such as math and science (Ainley et al. 2002; Denissen et al. 2007; Simpkins et al. 2006; Tai et al. 2006). More specifically, existing levels of interest are associated with both the way in which students experience a learning activity (i.e., how they engage with it) and their likelihood of participating in

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related future activities (i.e., their future choice preferences) (Ainley et al. 2002; Jacobs et al. 1998; Simpkins et al. 2006; Sha et al. 2015a). Engagement and choice have repeatedly been shown to relate to learning outcomes, such as improved academic performance (Patall 2013; Reber et al. 2009; Singh et al. 2002). These types of intermediate outcomes could be considered learning-relevant behavioral tendencies and drive outcomes associated with long-term learning and persistence in a domain.

We focus specifically on the case of interest in the domain of science because it is has received considerable empirical and policy attention. Mean levels of interest in science have been found to vary across countries (OECD 2007; Sjoberg and Schreiner 2010), by gender (Jenkins and Pell 2006), by ethnicity (Aschbacher et al. 2010), and by age (Osborne et al. 2003). Many studies note that science interest is especially sensitive during adolescence, as there is a frequent drop in science interest during this age (Bryan et al. 2011; Gottfried et al. 2001; Hawkey and Clay 1998; Osborne et al. 2003; Simpson and Oliver 1990). This particular decline onset has been much discussed because it co-occurs with time-sensitive science choices leading to future science opportunities (e.g., choosing science classes required for entrance into a STEM degree) (Tai et al. 2006; Tyson 2011). But it is also worth noting that particular experiences can lead to increases in interest (e.g., Hulleman and Harackiewicz 2009) and some environments can prevent declines in interest (Vedder-Weiss and Fortus 2011). In order to understand the causes of interest development or decline, as well develop appropriate interventions in and out of school, it is important to fully characterize the nature of interest and changes in interest.

Conceptualizations of interest

Interest is frequently conceptualized as a mixture of state, tendency, and emerging object: "a psychological state and a predisposition to reengage particular disciplinary content over time that develops through the interaction of the person and his or her development" (Renninger and Hidi 2011, p. 170). In terms of tendencies, interest in an activity or content is thought to influence both current enjoyment and future likelihood towards pursuing additional content or related situations (Ainley et al. 2002; Hidi and Renninger 2006). Because of this prominent effect of interest on enjoyment and participation, science educators frequently pay attention to the third aspect, interest as emerging object. That is, educators seek to encourage the development of interest, even if children have low initial science interest (e.g., Hidi and Harackiewicz 2000; Renninger and Hidi 2011). For example, environments encouraging personal meaning and active participation with novel and appropriately cognitively challenging material can help hold student attention and increase their interest in the situation at hand (e.g., Brophy 2013; Csikszentmihalyi 1997).

The three aspects of interest are captured in Hidi and Renninger's (2006) highly cited Four-Phase model of interest, where each phase is indicative of a deepening of interest, leading towards a consistent and personal development of interest towards a topic. In Phase 1 (Triggered Situational Interest), interest is generally initiated through an individual's positive interaction with the environment. This positive experience can lead to Phase 2 (Maintained Situational Interest), in which an individual continues to engage or re-engage with the topic that triggered their interest. These first two phases are largely driven by external support (although not exclusively), whereas later phases are identified through an individual's development of personal interest. Phase 3 (Emerging Individual Interest) is characterized by a greater degree of self-generated interest that continues to be bolstered by external supports (e.g., peer groups and positive learning experiences). In this phase, an individual has knowledge about the topic of interest, chooses to engage with the topic, and begins to wonder about and seek answers to questions about the topic. Finally, in Phase 4 (Well-developed Individual Interest), an individual has a foundation of knowledge on a topic, chooses to engage with this topic often in long-term endeavors that require repeated, consistent engagement, and seeks deeper answers to questions.

Overall, the Four-Phase model describes how an individual moves from a more environmentally-driven interest that is relatively unstable across time and context to a more robust interest that is stable across time and contexts. This influential model provides structure for conceptualizing interest development over time and experience. However, we argue the model is agnostic to the issue of topical breadth (i.e., the number of topics an individual finds interesting within a domain). While intensity of interest likely moves in parallel to interest development across the four phases, both narrowing and expansions of topical breadth of interest would be consistent with the model. For example, one could go from a triggered interest to well-developed interest in a narrow manner, such as a child who develops an early interest in animals to studying primarily biology through high school and into college. One could also imagine a broad pathway in which a child is interested in various science topics and cultivates these interests through diverse coursework and camps as the child grows. Alternatively, there could be shifts from narrow to broad interest or vice versa.

We argue that the level of science interest should be conceived as having two critical, potentially complimentary, dimensions: intensity of interest and breadth of interest. The purpose of the current work is to establish whether these dimensions are separable and to examine their potential independent relationships with learning tendencies.

Intensity of interest

Most science interest literature focuses on intensity of science interest measured at the general domain of "science" (e.g. "how interested are you in science?"; Hulleman and Harackiewicz 2009; Simpkins et al. 2006). Studies examining children's general science interest find children tend to have a positive interest in science at early kindergarten and elementary ages (Mantzicopoulos et al. 2008; Mantzicopoulos et al. 2009); however, as noted earlier, this general science interest tends to drop around middle school and level off before college (Gottfried et al. 2001; Osborne et al. 2003; Simpson and Oliver 1990).

Yet, this is not true of all students. Longitudinal data show that many students persist in their science interest and continue on to receive a science, technology, engineering, or math (STEM) degree (Logan and Skamp 2008; Maltese and Tai 2011; Maltese et al. 2014; Vedder-Weiss and Fortus 2011). Furthermore, differences in interest and positive attitudes towards science have been found across a variety of dimensions such as gender (e.g., Baram-Tsabari and Yarden 2008; Jacobs 2005; Jones et al. 2000) and ethnicity (e.g., Catsambis 1995; Perry et al. 2012; Zacharia and Calabrese Barton 2003).

The research linking science interest to engagement during science experiences (e.g., Lin et al. 2012) and choices to participate in optional science learning activities (e.g., Simpkins et al. 2006) has always used measures of intensity of science interest. For example, Sha et al. (2015a, b) show that interest influences student engagement and science preferences; however, this relationship focuses only on intensity of interest. Since breadth of science interest was not measured, it is possible the connections of interest to either engagement or choices are actually with breadth rather than intensity.

Breadth of interest

The question of breadth is especially salient in science, where there are full disciplines within science (e.g., biology or physics) and relatively large topics within those disciplines (e.g., botany or projectile motion). Thus, there is the important question about breadth of a given individual's science interest (whether situational or individual): with all of science, a discipline within science (e.g., biology), or a topic within a discipline (e.g., the topic of dinosaurs within the discipline of science). The breadth of interest will drive the decisions to participate and engage; e.g., a child interested in all science will likely choose to participate in a physics camp but a child only interested in biology presumably will not. Furthermore, breadth of interest could vary separately from intensity. For example, a child may be slightly interested in a broad range of topics and another may be intensely interested in only one or two.

Recently, there has been an increase in research establishing differences of interest across the domains of science (e.g., biology vs. physics) (ByBee and McCrae 2011; Schreiner and Sjoberg 2004; Trumper 2006a, b). Science degrees and careers are specialized into these domains, and students in the US are often given options in science coursework at the secondary level that allows for some specialization (e.g., advanced coursework in biology rather than basic coursework in physics). Additionally, it has been shown that students certainly find some topics more interesting than others (Ainley and Ainley 2011; Bathgate et al. 2013; ByBee and McCrae 2011; Jenkins and Pell 2006), but little research explores whether children vary in how many topics they finding interesting. Pragmatically, a child with many topical interests is more likely to find relevant resources in their local environment that support some interest in science than a child with narrow topical interests, unless a narrow topic interest was particularly popular in a child's community. Children with narrow topical interests may require different instructional strategies/curricular strategies to support maintenance and growth of their science interest.

A number of studies have examined students' discipline and topical science interest (e.g., ByBee and McCrae 2011; Jenkins and Pell 2006; Trumper 2006a, b). Such specific interests within science may reflect differential exposure, and some students are exposed to more areas of science (Jenkins and Pell 2006; Johnson et al. 2004). As a result of differential breadth of exposure and potentially quality of experiences across topics, children's intensity of interest may not overlap heavily with their breadth of interest.

Some children show narrow and specific interest in a particular science topic early in their development (Crowley and Jacobs 2002; Palmquist and Crowley 2007). For example, a child may take an early and intense interest towards dinosaurs or space travel, leading him or her to discover new facts through books, museum visits, activities, and discussion with caregivers. This specific interest can serve as a catalyst and outcome for science experiences and opportunities as a child approaches middle school and support the development of broader science interests. Alternatively, some children have an early general interest in science (even if they do not define it as such), but do not discover the topic for which they are passionate until later in high school, following a range of science experiences across different content (Maltese and Tai 2011; Maltese et al. 2014). These two alternatives describe examples of many different pathways children may take in their interest development (i.e., some may discover a narrow interest early, while others may develop a narrow passion during adolescence or perhaps that passion remains broad).

Breadth of interest may be driven by commonly occurring exposure to particular topics. That is, if children commonly learn about some science topic areas only in later schooling (e.g., chemistry), broad topic breadth in older populations might simply reflect the addition of particular topic area, as opposed to a commonly occurring expansion of interest with specific areas of expansion idiosyncratically determined.

Another possible underlying mechanism for determining interest breadth is that children's understanding of the contents of different sciences become refined with time and thus their interest levels for these particular topics become more refined with time. For example, a child excited by a science camp in paleontology might believe that other sciences are similar in content and thus similar in interest levels, but then later coursework or camp experiences demonstrate that other sciences are very different and therefore interests become more refined. Thus, the correlations of interest levels in one topic against interest levels in another topic may drop with experience, as interest expectations move from "science" as a whole to topics or disciplines within science, which, in turn, influences the breadth of interest.

These possible pathways and mechanisms of interest development provide a rationale for why intensity and breadth of interest should be separable. Before in-depth research should be conducted on these mechanisms and pathways, it is important to first establish that intensity and breadth do separate and that this separation is consequential for learning behaviors.

It is also important to note that relatively little is known about the effects of breadth of the interest on learning-relevant behavioral tendencies (i.e., behaviors that have an empirical relationship with learning outcomes). For example, does breadth of interest (rather than just depth of interest) drive these behavioral tendencies? We focus on two such tendencies: engagement and choice preferences.

Engagement

Engagement during science learning activities can be conceptualized of having affective, behavioral, and cognitive components and has been shown to relate to student learning and achievement (e.g., Fredricks et al. 2004, 2011). Affective engagement reflects the emotional component of participating in an activity (e.g., happiness, anxiety) with more positive affect relating to higher levels of performance (e.g., Linnenbrink 2007; Pekrun et al. 2009). Behavioral engagement refers to the specific overt behaviors one does that demonstrates engagement, such as attending class, asking questions, discussing ideas, or completing work (e.g., Fredricks et al. 2011). Finally, cognitive engagement involves the often covert processing of information, such as the degree of concentration or attention towards the task and making connections among ideas and explanations to better understand the content of an activity (see Fredricks et al. 2011 for a review of engagement).

Engagement here is used here as a self-reported outcome of interest; we expect that the degree to which one is interested in science content to influence the degree of engagement during science class. That is, those with more intense science interest should show greater positive affect, behaviors, and cognitive processing than those with less interest (e.g., Ainley and Ainley 2011). Furthermore, one's breadth of science interest may influence engagement, as a student with broader science interest may be more likely to find overlapping interest with the science content being presented and therefore be more engaged during the activity.

Science choice preferences

Science choice preferences refers to one's tendency to select science specific options from activities involving both science and non-science (e.g., art, sports) choices. Children have a significant degree of choice in how they spend their time outside of school, such as what they read or watch, which (if any) organized activities they participate in, or what activities they do in their free time at home. Preferences to participate in different kinds of informal science learning and optional school learning appear to be a coherent overall preference (e.g., those who wish to visit science museums are also those who wish to read books about science and take additional science classes; Sha et al. 2015a). These preferences have been associated in prior research with students' interest intensity (Sha et al. 2015b; Simpkins et al. 2006; Jacobs et al. 1998).

Both engagement and choice preferences could be conceived of as both a predictor and outcome of interest. That is, if a child has a positive science experience in which they are affectively, behaviorally, and cognitively engaged, this experience may increase their science interest. Additionally, if a child experiences more optional science learning experiences, their interest in science may increase. However, in the current work, we focusing on the outputs of interest: whether existing interests, in both breadth and intensity, predict later class engagement and likelihood of choosing optional science learning activities. Differences in the predictive nature of intensity and breadth would provide additional evidence regarding the independence and importance of intensity and breadth measures of interest.

In the currently reported studies, we first address the following questions: (*RQ1*) *Is there variation within breadth of interest and is that variation separate from intensity in science interest*? and (*RQ2*) *Are these results driven by particular relationships among topics preference (e.g., popular topic interests; high correlations among topic interests)*? We then examine the independent consequences of intensity and breadth of interest for learning-relevant behavioral tendencies. Specifically, we ask: *Do intensity and breadth of interest differentially predict student science engagement* (*RQ3*) *and science choice preferences* (*RQ4*)*?*

We select a middle school sample because this age of early adolescence is of particular importance for two reasons. First, declining science interest has been shown begin around middle school for many students (Gottfried et al. 2001; Osborne et al. 2003). Secondly, curricula prior to high school (and in some cases later middle school) are generally less differentiated and self-selected. That is, "science class" prior to middle school is taken by everyone and likely covers topics from a range of disciplines of science (e.g., earth science, physics) and as such, students entering middle school may not have strong delineations among the disciplines of science. Applying our framework of intensity and breadth of interest in this context provides information about the robustness of their separation.

Method

Participants

Roughly 700 sixth-grade middle school students were recruited, with 648 receiving parental consent to participate in the study. These students (49 % female; $M_{age} = 11.9$ years, $SD = .52$) were drawn from 9 urban public schools from the North Eastern United States, including primarily of schools consisting of grades 6–8, only two schools consisting of grades 6–12, and only one school consisting of grades K-8 (i.e., most 6th graders were in a new building that year). These middle schools (and their elementary feeder schools) use a common district-wide scripted inquiry curriculum (Full Option Science System), which focuses on hands-on activities. However, the curriculum was not aligned to the currently recommended Next Generation Science Standards (e.g., is had weak treatment of argumentation and student-directed experimentation). The curriculum covers a range of biology, physics, and earth science topics. Thus, these students had previously received a broad exposure to many science topics, and had sufficient prior experience to develop to the individual interest phases in the topics discussed here. All students were currently experiencing a unit on weather and climate (earth science), although the assessment was given very early in the school year and thus this specific topic exposure likely had little influence on responses.

Measures

General science interest

Students answered four items about the intensity of interest towards science. Since interest can be viewed as both cognitive and affective, these items have elements of both. Items were given on a 4-point Likert scale with opposing dimensions on either extreme ("When I work on science, I [*enjoy it…don't enjoy it*]"). Higher levels of interest (e.g., "enjoy it") were coded as four and lower levels (e.g., "don't enjoy it") were coded as one. Item-response theory analyses demonstrated a spread of roughly equal distance among our item responses (i.e., the psychological distance between the response items were similar to each other). As such, a mean of these items was computed and served as a general science interest measure (Cronbach's alpha $\geq$ .87; Principal component exploratory factor analyses showed a single factor with all loadings above .84).

These items were developed from reviewing existing motivational literature (e.g., ByBee and McCrae 2011 [PISA]; Germann 1988; Moore and Foy 1997 [SAI II]; Renninger et al. 2002; Schreiner and Sjoberg 2004 [ROSE]) and editing items to be science specific, appropriate for younger readers (middle-school aged), and to contain both cognitive and affective elements of interest and yet yielding a single factor.

These items were designed at a middle-elementary reading level to insure all 6th graders except the most reading-disabled students would be able to read them. Furthermore, cognitive interviews were conducted to establish the ability of all the instruments used in this study gather valid data at this age. A pilot group of 3–6 students per measure met 1:1 with a trained researcher and were instructed to read each item aloud, restate it in his/her own words, answer the item, and provide the reason for their selection. These pilot students were not the same students participating in the current study. Through this method, we were able to establish the items' theoretical relationship to interest and the confirm item interpretation for middle school students. Additionally, the high overall Cronbach's alpha (.83), item-to-total correlations, and principal components exploratory factor analysis (all loadings $>$ .79) with this 6th grade data demonstrate all interest intensity items contribute empirically to a strong overall scale.

Topic specific interest

As a measure of topic interest, students were given a list of topics within five science disciplines. To make sure participants had a clear understanding of the scope/content of each discipline regardless of amount of prior science instruction, each option included five topic examples (e.g., "animals, plants, cells, living things, life on earth") of a larger respective science discipline (e.g., biology). The items were as follows: (1) animals, plants, cells, living things, life on earth (biology); (2) stars, planets, the solar system, space travel, galaxies (astronomy); (3) chemicals, electricity, gravity, molecules, magnets (physical science); (4) oceans, weather, fossils, hurricanes, rocks & minerals (earth science); (5) robots, technology, rockets, bridges & buildings, how computers work (engineering). The particular topic examples for each discipline were based on prior work on topics with high familiarity. Furthermore, Bathgate et al. (2013) used a very similar set of topics (e.g., animals, stars, gravity) and found attitudes towards these topics clustered into their respective larger disciplines (e.g., biology, astronomy) and were not strongly driven by interest in just one particular topic. In other words, students who tend to like one biology topic also tend to like the other topics within biology.

Students were asked to report their interest towards each item's content by checking a box in front of each item. A "1" was given for each of the options they selected and a "0" otherwise. A breadth score was calculated by summing students' reported interest across the five items to produce a breadth score of 0–5.

A binary approach was used due to the primary goal of examining the number of interest areas. Variables with three or more response options (e.g., "how much do you like [a given topic]?") would have needed to undergo a binary split in order to calculate a breadth score and the sum of binned Likert topic items inherently embeds some degree of intensity, which confounds the two dimensions, making the current methodology sufficient to answer whether we can detect separation between intensity and breadth.

Engagement

Engagement is sometimes considered within a large context, such as engagement in academics over an unspecified amount of time (e.g., "I pay attention in class"; Martin 2009); however, such an approach can create confusions between interest and engagement as constructs and measures. Our approach focuses on self-reported engagement in science classroom activities, and uses a methodology of repeatedly collected data on engagement on tasks that were just completed. This approach affords a finer-grained measure of engagement within a narrow context without relying on memory of a distant event.

The engagement scale consists of 17-items. There were affective (e.g., "During today's activity, I felt bored" [reversed]), behavioral (e.g., "During today's activity, I tried out my ideas to see what would happen"), and cognitive (e.g., "I figured out something about science") items asking about students' engagement with the immediately preceding class. Items were presented on a 4-point scale (YES!, yes, no, NO!) shown to be easy and effective for children of this age to interpret (Sha et al. 2015b). A previous validation study of the engagement measure has shown its structure to be stable across days (i.e., the factor structure, averages of items, response distributions) and that the use of an overall engagement score was psychometrically appropriate (as opposed to affective, behavioral, and cognitive subscores) (see Sha et al. 2015b). Alphas for each of the 4 days ranged from .83 to .87 and the alpha for the average of the 4 days used to compute our outcome variable was .84. A principal component exploratory factor analysis shows that the average for the 4 days cohere into a single factor with loadings > .76.

Choice preference

Because different children might have different constraints on which optional activities are available (e.g., access to the library, financial resources to attend summer camps or weekend programs) and the different levels of autonomy in making choices (e.g., parents who exert strong control over program attendance), we do not focus on actual choices that were made (Sha et al. 2015a). Instead, we focus on the child's influence on choices: the choice preferences scale assesses a child's preference for science activities when presented with typically occurring alternatives.

In particular, our choice preference measure consists of four 4-alternative choice items that present students with activities involving science or an alternative content (e.g., math, art) purposefully drawn from a range of formal (e.g., school) and informal (e.g., home, museum) contexts. For example, "If you were allowed to pick your classes for next year, which ones would you pick?: Art, English, History, Math, Music, Science, None of these;" "Imagine that today you get to take one of these activities home with you to do, which activity would you choose?: An art project, a musical instrument, a math puzzle, a science experiment?" For each item, students selected one option. An item was coded "1" is a student selected the science choice and a "0" if selecting a non-science option. A choice-preference score was generated by adding the four items; Thus, each student received a score of 0–4. The purpose of this instrument is gauge students' preference for science when presented with common alternative topics. See Sha et al. (2015a) for details on the design and validation of this instrument.

Procedure

At the beginning of the school year, middle school students completed the interest measures online or on paper during students' science classes; no differences were found across method. That is, there were no differences in the average intensity score (or breadth score) when comparing online vs. paper responses via a between-subjects *t* test. The paper-based engagement measure was given four times (approximately every 3 weeks) at the end of students' science classes across a 3-month period following the interest measure collection. Since teachers varied in their pace of covering the FOSS curricula, the engagement surveys were given to students at the end of the same four lessons (as opposed to date-specific data collection) to control for this difference in pace. The activities completed on these 4 days were each on weather and water topics and were specifically selected not to be test days, but to variation in the kinds of activities (e.g., focused on data collection, readings, class discussion, or worksheet completion). An average across the 4 days for students completing at least three engagement surveys is used for our analyses; students present for less than three engagement administrations were not included in our engagement analyses, resulting in diminished sample sizes for some of our analyses (e.g., regressions in "Do intensity and breadth of interest differentially predict student science engagement?" section).

The paper-based choice preference measure was collected in students' science classes on a separate day shortly after collecting the interest measures. All students were informed their responses to all measures would not be shown to their teacher and would not influence their grade.

Results

Is there variation within and separation between breadth and intensity of interest?

We first examine descriptive statistics of the distribution of general science interest scores to rule out floor and ceiling effects in either sample that would complicate analyses of inter-relationships with general interest. Middle school students have a mean of mildly positive general interest in science on the 4-point scale ($M = 3.3$, $SD = 0.7$). About 8 % of middle students responded with an average negative general science interest (mean < 2.0) (e.g., they did not enjoy science, found it boring) and ~20 % have a mean below 3.0; as is typically found at the beginning of middle school interest in many disciplines is still relatively high, including science. Note that the high alpha value for the interest intensity measure shows that there still is significant variation across students in general science interest levels. In regard to breadth of interest, Fig. 1 shows students vary widely in number of interest topics. This pattern eliminates the concern for ceiling and floor effects, as students are not consistently strongly positive or negative towards science or the topics measured.

Next, we use to Pearson correlations to examine the strength of the relationship between students' general science interest mean and the sum of topics selected to ask whether these variables are highly related (i.e., the greater the interest one has in science, the more science topics are interesting). We find a small but significant correlation between general science interest the topic breadth ($r = .16$, $p = .001$; ~3 % shared variance); thus, general interest and breadth of interest can be reasonably examined separately and in conjunction.

To further explore the relationship between intensity and breadth, we plotted mean science interest (rounded to the nearest whole number) against number of selected topics. Figure 2 shows mean science interest (rounded to the nearest whole number) plotted against topic breadth and the density of middle-school students occupying this two-dimensional space. Darker shades represent a greater degree of overlap between the science interest and topic breadth. Most students have positive interest in science, but are widely distributed in the number of topics they prefer. About 28 % of students have positive science interest and are interested in 4–5 topics (lower right area). About 43 % have a positive science interest with only 1–2 topic interest (upper right area). However, even

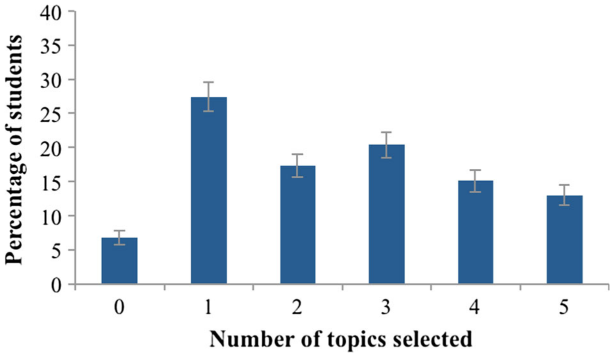

Fig. 1 Histogram of number of interest topics selected by students with SE bars

Fig. 2 Relative frequencies of combinations of intensity and breadth of science interest

	General Interest			
	strong -	weak -	weak +	strong +
# topics	1	2	3	4
1	1%	2%	13%	13%
2	0%	2%	7%	10%
3	0%	2%	8%	12%
4	0%	1%	6%	9%
5	0%	1%	5%	8%

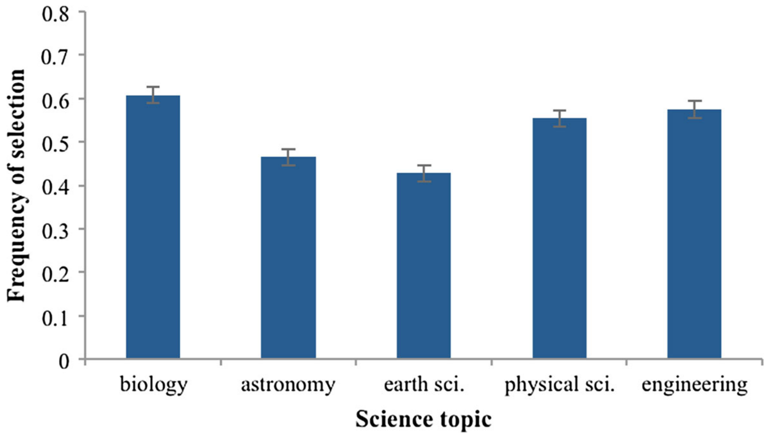

Fig. 3 Mean topic selection frequency with SE bars

within overall positive interest, 13 % of students are intensely interested in science but have only one topic area of interest (upper right corner cell) and 5 % of students have lower positive overall interest in science but consider all five topics interesting. Few students (~2 %) have 4–5 topic interests but have little general science interest (lower left area), but about 9 % of students are interested in at least one topic even if they generally are not interested in science overall (left half).

Are these results driven by particular relationships among topic preference?

Does the breadth/general interest difference simply reflect differences in particular topics of interest rather than general patterns of topic breadth per se? A repeated measure generalized linear model was used to test for differences in topic interest (see Fig. 3 for topic category means). Specifically, each topic area served as a within-subjects independent variable with the frequency of selection (how many students selected each topic area) as the outcome to determine if there were differences in interest for each topic area. There is a main effect of topic (F[3.84,[1] 59]) $= 12.51$, $p < .001$, $\eta^2 = .02$) and pairwise comparisons

[1] Mauchly's test for sphericity was significant for all ANOVA statistics reported here, meaning the variance within the two samples was significantly different. Therefore, Greenhouse-Geisser corrected degrees of freedom was used to determine F values.

shows interests among topics are significantly different from each other (all ≤ .02) with the exception of biology with engineering and astronomy with earth science, which are similar in frequency. Effect sizes are small (Cohen's $d = .12$–$.26$ among the significantly different comparisons), with the strongest effects between biology and astronomy ($d = .26$), biology and earth science ($d = .26$), astronomy and engineering ($d = .25$), and earth science and engineering ($d = .25$). This pattern shows there is no single topic that drives our findings in a systematic manner.

Finally, Pearson correlations among topic selections were computed to explore whether there are common clusters of specific interest. We had asked students to identify interests at the disciplinary level (i.e., biology, physics, etc.), but it is possible that interests are actually displayed in larger clusters. Correlations among topic preferences are shown in Table 1 and are small (e.g., earth science and engineering) to low-moderate (biology and earth science). While there is some degree of shared interest among the topics, preferences are still generally independent (i.e., there are no strong clusters of interest).

Research questions 1 and 2 provide clear evidence of separation of interest intensity and interest breadth in this sample. Weak intensity is commonly associated with low breadth, but high intensity is found actually found more often with low breadth than with high breadth. Patterns of breadth cannot be reduced to interest in common vs. rare interest topics; topic interest areas were relatively independent.

Do intensity and breadth of interest differentially predict student science engagement?

A linear regression was run with intensity of interest and breadth of interest predicting students' engagement. Prior to this analysis, the data were screened to confirm the assumptions of multiple regressions were met: there are no extreme outliers; multicollinearity among our predictor variables was ruled out (VIF = 1.02); and distribution of our predictor variables were checked (there was a slight negative skew for topic breadth, but enough variation to continue the analysis; see means and range in "Is there variation within and separation between breadth and intensity of interest?" section). The regression shows only intensity of interest is a significant predictor of science class engagement (adj $R^2 = .10$; $F(2,386) = 21.72$, $p < .001$; see Table 2).

Additionally, due to the nested nature of the data (students are nested within school), we also ran a two-level hierarchical linear regression with a school-level variable in the first level. Additionally, since one teacher from each school participated, school-level variance and teacher-level variance were entirely overlapping. Thus, teacher-level variance was not considered separately. This two-leveled regression showed that school-level variance does not account for any significant variance in engagement (i.e., school level variance accounted for 0.003 % of the variance) and the findings are consistent with those obtained from the simple multiple regression.

Does interest breadth and intensity predict students' choice preferences?

Intensity and breadth of interest were again entered as predictors, but this time with choice preferences as the outcome. In this case, both intensity and breadth of interest independently predict choice preferences (adj $R^2 = .09$; $F(2,482) = 25.27$, $p < .001$ l; See Table 2). Similar to the regression for engagement, we also conducted a two-level hierarchical linear regression with school-level data in the first level. Again we found school

Table 1 Pearson correlations among topic variables

	Biology	Earth sci.	Engineering	Physical sci.
Astronomy	.19**	.28**	.21**	.23**
Biology		.33**	.16**	.17**
Earth sci.			.11**	.15**
Engineering				.32**

* $p < .005$, ** $p < .001$

Table 2 Standardized betas for predicting engagement and choice preferences

Predictor	Standardized beta coefficients
Predicting science class engagement	
Intensity of interest	.31***
Breath of interest	.03
Predicting science choice preferences	
Intensity of interest	.26***
Breath of interest	.13***

Note Sample size varies largely due to class attendance, particularly across the multiple engagement collections. $N = 388$ for engagement and $N = 484$ for choice preferences

*** = $p < .001$

variance not to account for any significant variance in choice preference (school level variance accounted for 0.004 %), and the intensity and breath of interest effects replicated.

Discussion

Intensity and breadth are separable

Our current work unpacks the relationship between breadth and intensity of science interest. In our middle school sample, there is statistically significant overlap between interest intensity and interest breadth. But, perhaps counter to common expectation, this overlap is only 3 %. Additionally, all extreme subgroups exist, ranging from students' who are intensely interested in all areas to intensely interested in only one area to those who are mildly interested in only one area.

Recent work suggests these patterns in breadth occur frequently. New evidence from retrospective interviews described in Crowley, Barron, Knutson, and Martin (Crowley et al. 2014) recounts shifts in science interest across the lives of roughly 70 scientists, science educators, and other science professionals. They found variation in the consistency of breadth, as well as variation in the maintenance of particular topic interest across scientists' lives. Most scientists did not pursue a career in the topic with which they were first interested, yet a subset (16 %) of scientists did take a direct route from their initial topic of interest to a career within this interest (e.g., astronomy, paleontology).

As the intensity and breadth dimensions are separable in our sample, the question arises: what drives intensity and what drives breadth? Several factors have been connected to a decline in the intensity of general science interest, such as struggling with success in science (Simpkins et al. 2006), identification with a peer groups outside of science

(Aschbacher et al. 2010; Eckert 1989; Fraser and Kahle 2007), and negative science experiences (Jarrett 1999). Less is known about how and why differences in breadth of interest occur, although research is continuing to address these questions (Crowley and Jacobs 2002; Palmquist and Crowley 2007). Additionally, the breadth and depth framing could be used to elaborate the Four-Phase model of interest, examining how changes in breadth and depth are connected to changes in situational vs. individual interest.

Intensity and breadth are predictive

As previous work would predict (Ainley et al. 2002; Hidi and Renninger 2006), interest is associated with positive behavioral learning-related tendencies, but we show that intensity of interest and breadth of interest are also associated in meaningfully different ways. These data suggest our two outcomes may be driven by different factors and differently related with depth and breath, highlighting the importance of considering this framework in interest research. Controlling for interest breadth, intensity of interest is related to both higher self-reported engagement and greater preference for science activities in our sample; the more intense one's interest in science, the more likely one is engaged in science class and more likely to prefer science activities from alternative options. However, controlling for interest intensity, breadth of interest is only positively associated with choice preferences, not engagement.

Why does breadth show a relationship with choice preference and not engagement (above the effects of interest intensity)? One possible explanation is we examined engagement in a science classroom over an extended time period, in which a general interest in science can be deepened into interest in the specific topic area covered that semester. By contrast, choice preference presents more self-driven options for students in which a priori interest levels in the likely science content will matter; for example, a learner primarily interested in biology topics might develop sufficient interest in the climate and weather topic to engage productively in the lessons (as there often cross topic connections), whereas such a learner might be more suspicious of going to a general science museum or completing a science experiment in which the topic is not their current favorite. This pattern of results demonstrates the utility of considering intensity and breadth in relationship to outcomes such as participation in future science activities and students' engagement within these experiences. Applying this framework to additional outcome variables (e.g., classroom learning, career preferences, future science class selection) will extend our knowledge of the interest's relationship with learning related outcomes; specifically, whether breadth or intensity drives particular types of outcomes.

Implications for research

Given the moderate correlation that we observe between breadth and depth, of interest, past studies of student science interest may have inadvertently captured interest intensity or breadth, or may have found contradictory findings for one dimension when not considering the interacting role of the other dimensions. Routinely measuring both breadth and intensity will be critical to expand our understanding of the relationship between these variables and their impact on additional learning outcomes (e.g., science achievement, participation in science activities), as well as demonstrating their malleability.

In the current study, a single interest item for each science domain was used and likely measures an emotive state of a child's current interest, but not the wider nature of a student's interest in a topic (e.g., how they engage, under what circumstances) (Ainley and

Patrick 2006). More indepth measurement of topic interest, including examination of specific topics within categories, can inform the ways in which breadth and intensity influence children's science experiences. This current work suggests that there is an important distinction between intensity and breath of interest and demonstrates a fruitful path for future interest work. Furthermore, this framework could be applied to examine breadth and intensity relationships in samples that have previously shown overall interest and attitude differences towards science (e.g., gender, Jones et al. 2010; socioeconomic status, Perry et al. 2012).

Implications for education

Considering levels of intensity and breadth of interest in tandem could illuminate patterns within the typical decline in science interest found in middle and high school grades (Bryan et al. 2011; Gottfried et al. 2001; Osborne et al. 2003). Specifically, are students with particular levels of breadth or intensity buffered again or most at-risk for decline? For example, children with very narrow science interests are likely to be especially at risk for declines in interest: (1) they will have few optional science learning experiences that seem relevant to them, unless their family or community is well resourced, so they will be exposed to less informal science; and (2) they show lower levels of engagement in required science classes which will primarily involve other topics. Allowing science projects that allow for broad topic choice, rather than forcing topics to match the curriculum, may be a way of sustaining interest for these narrow topic interest students.

Another group deserving special attention are those students with broad but low science interest. It may be that these students have seen too little exposure to authentic science experiences in elementary school (i.e., science experiences that mimic professional practice of science), which is a common occurrence (Anderson et al. 1996; Barab and Duffy 2000; Sadler et al. 2010), and simply have not yet been exposed to topics within the broad disciplines and careers found within the science umbrella. A strategy of combining reading instruction with science instruction in the elementary years that exposes students to more diverse science topics may be an effective strategy for dealing with this concern (Cervetti et al. 2006; Goldschmidt and Jung 2010; Guthrie et al. 2004), as well as synthesizing across in-school and out-of-school spaces (Bell et al. 2009), or introducing students to communities of professional scientists (Barab and Hay 2001; Sadler et al. 2010).

References

Ainley, M., & Ainley, J. (2011). Student engagement with science in early adolescence: The contribution of enjoyment to students' continuing interest in learning about science. *Contemporary Educational Psychologist, 36*, 4–12.

Ainley, M., Hidi, S., & Berndorff, D. (2002). Interest, learning, and the psychological processes that mediate their relationship. *Journal of Educational Psychology, 94*(3), 545–561. doi:10.1037//0022-0663.94.3.545.

Ainley, M., & Patrick, L. (2006). Measuring self-regulated learning processes through tracking patterns of student interaction with achievement activities. *Educational Psychology Review, 18*, 267–286.

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational Researcher, 25*(4), 5–11.

Aschbacher, P. R., Li, E., & Roth, E. J. (2010). Is science me? High school students' identities, participation and aspiration in science, engineering, and medicine. *Journal of Research in Science Teaching, 47*(5), 564–582.

Barab, S. A., & Duffy, T. M. (2000). From practice fields to communities of practice. In D. Jonassen & S. Land (Eds.), *Theoretical foundation of learning environments*. Mahwah, NJ: Erlbaum.

Barab, S. A., & Hay, K. E. (2001). Doing science at the elbows of experts: Issues related to the science apprenticeship camp. *Journal of Research in Science Teaching, 38*(1), 70–102.

Baram-Tsabari, A., & Yarden, A. (2008). Girls' biology, boys' physics: Evidence from free-choice science learning settings. *Research in Science & Technological Education, 26*(1), 75–92.

Bathgate, M. E., Schunn, C. D., & Correnti, R. (2013). Children's motivation towards science across contexts, manner-of-interaction, and topic. *Science Education, 98*(2), 189–215.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning science in informal environments: People, places and pursuits*. Washington, DC: The National Academies Press.

Brophy, J. E. (2013). *Motivating students to learn* (3rd ed.). London: Routledge.

Bryan, R. R., Glynn, S. M., & Kittleson, J. M. (2011). Motivation, achievement, and advanced placement intent of high school students learning science. *Science Education, 95*(6), 1049–1065. doi:10.1002/sce.20462.

ByBee, R., & McCrae, B. (2011). Scientific literacy and student attitudes: Perspectives from PISA 2006 science. *International Journal of Science Education, 33*(1), 7–26.

Catsambis, S. (1995). Gender, race, ethnicity, and science education in the middle grades. *Journal of Research in Science Teaching, 32*(3), 243–257.

Cervetti, G. N., Pearson, P. D., Bravo, M. A., & Barber, J. (2006). Reading and writing in the service of inquiry-based science. In R. Douglas, M. P. Klentschy, & K. Worth (Eds.), *Linking science and literacy in the K-8 classroom* (pp. 221–244). Arlington, VA: National Science Teachers Association Press.

Crowley, K., Barron, B., Knutson, K., & Martin, C. K. (2014). Pathways to children's development of interest in science. In K. A. Renninger, M. Nieswandt, & S. Hidi (Eds.), *Interest in mathematics and science learning and related activity*. Washington DC: AERA.

Crowley, K., & Jacobs, M. (2002). Building islands of expertise in everyday family activity. In K. Crowley & K. Knutson (Eds.), *Learning conversations in museums* (pp. 333–356). Mahwah, NJ: Lawrence Erlbaum.

Csikszentmihalyi, M. (1997). Intrinsic motivation and effective teaching: A flow analysis. In J. Bess (Ed.), *Teaching well and liking it: Motivating faculty to teach effectively* (pp. 72–89). Baltimore: The John Hopkins Press.

Denissen, J. H., Zarrett, N. R., & Eccles, J. S. (2007). "I like to do it, I'm able, and I know I am": Longitudinal couplings between domain-specific achievement, self-concept, and interest. *Child Development, 78*, 430–447.

Eckert, P. (1989). *Jocks and burnouts: Social categories and identity in the high school*. New York: Teachers College Press.

Fraser, B. J., & Kahle, J. B. (2007). Classroom, home, and peer environment influences on student outcomes in science and mathematics: An analysis of systemic reform data. *International Journal of Science Education, 29*(15), 1891–1909.

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109.

Fredricks, J., McColskey, W., Meli, J., Mordica, J., Montrosse, B., and Mooney, K. (2011). Measuring student engagement in upper elementary through high school: A description of 21 instruments. (Issues & Answers Report, REL 2011–No. 098). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southeast.

Germann, P. J. (1988). Development of the attitude toward science in school assessment and its use to investigate the relationship between science achievement and attitude toward science in school. *Journal of Research in Science Teaching, 25*(8), 689–703.

Goldschmidt, P., & Jung, H. (2010). *Evaluation of Seeds of Science/Roots of Reading: Effective tools for developing literacy through science in the early grades.* Los Angeles: National Center for Research on Evaluation, Standards, and Student Testing and University of California.

Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic motivation from childhood to late adolescence: A longitudinal study. *Journal of Educational Psychology, 82*, 525–538.

Guthrie, J. T., Wigfield, A., Barbosa, P., Perencevich, K. C., Taboada, A., Davis, M. H., et al. (2004). Increasing reading comprehension and engagement through concept-oriented reading instruction. *Journal of Educational Psychology, 96*(3), 403.

Hawkey, R., & Clay, J. (1998). Expectations of secondary science: Realisation and retrospect. *School Science Review, 79*(289), 81–83.

Hidi, S., & Harackiewicz, J. M. (2000). Motivating the academically unmotivated: A critical issue for 21st century. *Review of Educational Research, 70*(2), 151–179.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127.

Hulleman, C. S., & Harackiewicz, J. M. (2009). Promoting interest and perforamnce in high school science classes. *Science, 326*(5958), 1410–1412.

Jacobs, J. E. (2005). Twenty-five years of research on gender and ethnic differences in math and science career choices: What have we learned? In J.E. Jacobs & S.D. Simpkins (Eds.), *New Directions for Child and Adolescent Development, 110*, 85–94.

Jacobs, J. E., Finken, L. L., Griffin, N. L., & Wright, J. D. (1998). The career plans of science-talented rural adolescent girls. *American Educational Research Journal, 25*, 681–944.

Jarrett, O. S. (1999). Science interest and confidence among preservice elementary teachers. *Journal of Elementary Science Education, 11*(1), 49–59.

Jenkins, E. W., & Pell, R. G. (2006). *The relevance of science education project (ROSE) in England: A summary of findings*. Leeds: Centre for Studies in Science and Mathematics Education, University of Leeds.

Johnson, K. E., Alexander, J. M., Spencer, S., Leibham, M. E., & Neitzel, C. (2004). Factors associated with the early emergence of intense interests within conceptual domains. *Cognitive Development, 19*, 325–343.

Jones, M. G., Howe, A., & Rua, M. J. (2010). Gender differences in students' expereinces, interests, and attitudes towards science and scientists. *Science Education, 84*, 180–192.

Lin, H. S., Hong, Z. R., & Huang, T. C. (2012). The role of emotional factors in building public scientific literacy and engagement with science. *International Journal of Science Education*, *34*(1), 25–42.

Linnenbrink, E. A. (2007). The role of affect in student learning: A multi-dimensional approach to considering the interaction of affect, motivation, and engagement. In P. Schutz & R. Pekrun (Eds.), *Emotion in Education* (pp. 107–124). San Diego, CA: Academic Press.

Logan, M., & Skamp, K. (2008). Engaging students in science across the primary secondary interface: Listening to students' voice. *Research in Science Education, 38*(4), 501–527.

Maltese, A. V., Melki, C. S., & Wiebke, H. (2014). The nature of experiences responsible for the generation and maintenance of interest in STEM. *Science Education, 98*(6), 937962.

Maltese, A. V., & Tai, R. H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among U.S. students. *Science Education, 95*(9), 877–907.

Mantzicopoulos, P., Patrick, H., & Samarapungavan, A. (2008). Young children's motivational beliefs about learning science. *Early Childhood Research Quarterly, 23*(3), 378–394. doi:10.1016/j.ecresq.2008.04.001.

Mantzicopoulos, P., Samarapungavan, A., & Patrick, H. (2009). "We Learn How to Predict and be a Scientist": Early science experiences and kindergarten children's social meanings about science. *Cognition and Instruction, 27*(4), 312–369. doi:10.1080/07370000903221726.

Martin, A. J. (2009). *The motivation and engagement scale*. Sydney: Lifelong Achiemvent Group.

Moore, R. W., & Foy, R. L. H. (1997). The scientific attitude inventory: A revision (SAI II). *Journal of Research in Science Teaching, 34*(4), 327–336.

OECD. (2007). *PISA 2006. Science competencies for tomorrow's world.* Author: Paris.

Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education, 25*(9), 1049–1079.

Palmquist, S. D., & Crowley, K. (2007). From teachers to testers: Parents' role in child expertise development in informal settings. *Science Education, 91*(5), 712–732.

Patall, E. A. (2013). Constructing motivation through choice, interest, and interestingness. *Journal of Educational Psychology, 105*(2), 522–534.

Pekrun, R., Elliot, A. J., & Maier, M. A. (2009). Achievement goals and achievement emotions: Testing a model of their joint relations with academic performance. *Journal of Educational Psychology, 101*(1), 115.

Perry, B. L., Link, T., Boelter, C., & Leukefeld, C. (2012). Blinded to science: Gender differeces in the effects of race, ethnicity, and socioeconomic status on acadmic and science attitudes among sixth graders. *Gender and Education, 24*(7), 725–743.

Reber, R., Hetland, H., Weiqin, C., Norman, E., & Kobbeltvedt, T. (2009). Effects of example choice on interest, control, and learning. *Journal of Learning Sciences, 18*(4), 509–548.

Renninger, K. A., Ewen, L., & Lasher, A. K. (2002). Individual interest as context in expository text and mathematical word problems. *Learning and Instruction, 12*, 467–491.

Renninger, K. A., & Hidi, S. (2011). Revisiting the conceptualization, measurement, and generation of interest. *Educational Psychologist, 46*(3), 168–184.

Sadler, T. D., Burgin, S., McKinney, L., & Ponuan, L. (2010). Learning science through research apprenticeships: A critical review of the literature. *Journal of Research in Science Teaching, 47*(3), 235–256.

Schreiner, C., & Sjoberg, S. (2004). *Sowing the seeds of ROSE. Background, Rationale, Questionnaire Development and Data Collection for ROSE (The Relevance of Science Education)–a comparative study of students' views of science and science education.* (4/2004), Oslo: Department of Teacher Education and School Development, University of Oslo.

Sha, L., Schunn, C. D., & Bathgate, M. E. (2015a). Measuring choice to participate in optional science learning experiences during early adolescence. *Journal of Research in Science Teaching, 52*(5), 686–709. doi:10.1002/tea.21210.

Sha, L., Schunn, C. D., Bathgate, M. E., & Ben-Eliyahu, A. (2015b). Families support their children's success in science learning by influencing interest and self-efficacy. *Journal of Research in Science Teaching,*. doi:10.1002/tea.21251.

Simpkins, S. D., Davis-Kean, P. E., & Eccles, J. S. (2006). Math and science: A longitudinal examination of the links between choices and beliefs. *Developmental Psychology, 42*(1), 70–83. doi:10.1037/0012-1649.42.1.70.

Simpson, R. D., & Oliver, J. S. (1990). A summary of major influences on attitude toward and achievement in science among adolescent students. *Science Education, 74*(1), 1–18.

Singh, K., Granville, M., & Dika, S. (2002). Mathematics and science achievment: Effects on motivation, interest, and academic engagement. *Journal of Educational Research, 95*, 323–332.

Sjoberg, S., & Schreiner, C. (2010). *The ROSE project: An overview and key findings*. Olso: University of Oslo.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. T. (2006). Planning early for careers in science. *Science, 312*, 1143–1144.

Trumper, R. (2006a). Factors affecting junior high school students' interest in biology. *Science Eduation International, 17*(1), 31–48.

Trumper, R. (2006b). Factors affecting junior high school students' interest in physics. *Journal of Science Education and Technology, 15*(1), 47–58. doi:10.1007/s10956-006-0355-6.

Tyson, W. (2011). Modeling engineering degree attainment using high school and college physics and calculus coursetaking and achievement. *Journal of Engineering Education, 100*(4), 760–777.

Vedder-Weiss, D., & Fortus, D. (2011). Adolescents' declining motivation to learn: Inevitable or not? *Journal of Research in Science Teaching, 48*(2), 199–216.

Zacharia, Z., & Calabrese Barton, A. (2003). Urban middle-school students' attitudes toward a defined science. *Science Education, 88*(2), 197–222.