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Evaluation of a Process by which Individual Interest Supports Learning within a Formal Middle School Classroom Context

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Abstract

The affective domain and its impact on science achievement has been studied with increasing attention over the past decade. However, there has been little empirical work on how individual interest, and facilitation of situational interest in the classroom, facilitates learning of concepts within fine-grained units of instruction. Drawing upon previous theoretical and empirical work, we test the hypothesis that individual interest facilitates situational interest, and that this in turn facilitates content learning, with respect to a 10-day health education intervention focused on teaching middle school students about light, color and vision. We found that individual interest in science facilitates situational interest in the classroom activities and the teacher's instruction, and that situational interest has a positive and significant effect on learning concepts related to light and vision. Our data suggest that facilitating situational interest is a requirement if individual interest and prior knowledge are to be effective scaffolds for conceptual learning. However, targeting of other affective traits like motivation and engagement or cognitive processes like goal setting may be necessary to fully harness students' interest toward effective scaffolding of learning.

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Keywords

conceptual change; individual interest; motivation; path analysis; situational interest

Introduction

Current K-12 education standards emphasize mastery of outcomes associated with science content, scientific reasoning, and scientific practice (NGSS Lead States, 2013), but little on the goal of increasing interest in science. Sanders (2009) states: “If America hopes to effectively address the ‘STEM pipeline’ problem, we must find ways of developing young learners’ interest” (p. 22). Attracting and retaining students in science remains a complex problem, where we are required to facilitate interest while also teaching the content and practices necessary for higher studies (Sanders, 2009; Subotnik, Tai, Rickoff, & Almarode, 2009).

These two goals do not have to be treated as mutually exclusive. Knowledge and interest in science tend to be positively correlated: science literacy may represent an integration of thinking and feeling processes (Bransford, Brown, & Cocking, 1999; Treagust & Duit, 2008). The willingness to put in effort to learn is an important manifestation of interest (Krapp & Prenzel, 2011); it follows that while interest is triggered as a feeling towards a topic (Hidi, 2006), it becomes integrated with cognitive processes like goal-setting as it develops over time (Krapp, 2002). Promoting interest improves conceptual understanding (Nieswandt, 2007), problem solving (McLeod & Adams, 1989), and performance in coursework (Schiefele, Krapp, & Winteler, 1992; Glynn, Taasobshirazi, and Brickman, 2007).

The link between facilitation of interest and learning has been qualified through theoretical and meta-analytical work (Hidi & Renninger, 2006), and a positive relationship between interest and academic performance has been established in empirical work across diverse groups (i.e. Nieswandt, 2007; Harackiewicz, Durik, Barron, Linnenbrink-Garcia, & Tauer, 2008; Rotgans & Schmidt, 2011). However, the effect of interest on learning within a specific, short-duration instructional context has not received such attention. We propose a conceptual framework for evaluating the effect of interest on learning within short-duration instructional contexts and use it to explore the process by which interest supports content learning in the context of middle school (grades 7 and 8) health science instruction. Although we believe that understanding how interest develops and supports learning is important within any arena of STEM and at any grade level, our choice to focus on a middle school health sciences context is motivated by the need to create a more health literate society (Joint Committee on National Health Education Standards, 2007) combined with the imperative of recruiting and retaining participants in our health workforce (Kelley et al. 2004) to support an aging world population (National Research Council, 2001). To this end, the choice to focus on middle school in particular is motivated by work suggesting that this is a critical age to get students interested in the sciences and into the STEM pipeline. Middle school is a time when students experience significant changes in their thinking, interests, and social lives (Adams & Berzonsky, 2003). Students’ engagement in middle school can

profoundly impact the goals they end up pursuing through high school and into their careers. This is an especially important age to study how classroom experience may capitalize on students' dispositions to support learning (Ryan & Patrick, 2001).

Literature Review

Unlike variables like motivation (Glynn et al., 2007), engagement (Renninger & Bachrach, 2015), self-efficacy (Hidi, Berndorff, & Ainley, 2002), and achievement goals (Hidi & Harackiewicz, 2000), interest manifests as a psychological state as opposed to an action orientation (Ainley, Hidi, & Berndorff, 2002). An individual may display motivation, engagement, and self-efficacy despite lack of interest due to behavioral dispositions such as the perceived need to achieve a desired level of performance in a task (Hidi & Harackiewicz, 2000).

Individual and situational interest can be characterized ontologically as two distinct psychological states. Individual interest is a dispositional tendency toward a topic or area of study developed over a student's lifetime (Renninger, 2009), and tends to be difficult to change (Authors, 2014). Situational interest, by comparison, is more environment-specific and transitory (Ainley, 2006), changing readily in response to a specific learning situation or environment (Hidi & Harackiewicz, 2000). Delineation of individual and situational interest begs the question of whether such a distinction is ontological or epistemological. Are these distinct parts of a student's reality, or were these constructed as convenient categories to be used by researchers? As we discuss prior work on interest and how it may relate to learning, we take the ontological perspective, treating individual and situational interest as two distinct psychological states that support each other (Hidi & Renninger, 2006), and in turn support learning (Schiefele, 2001). We discuss prior work evidencing these relationships to follow.

Connection between Individual and Situational Interest

Much of the theoretical and empirical work exploring the connection between individual and situational interest has been contextualized in terms of student development over semesters or years. Hidi and Renninger (2006) suggest that situational interest facilitates a student's individual interest in four phases: (1) situational interest is triggered; (2) situational interest is maintained; (3) individual interest emerges, and (4) individual interest becomes well-developed (Hidi & Renninger, 2006). More recent empirical work also supports this progression. For example, Linnenbrink-Garcia et al. (2010) demonstrate that, in adolescents, situational interest is quite distinct from individual interest, and that situational interest is a statistically significant predictor of change in individual interest across a school year.

Due to the relatively stable nature of individual interest, efforts to make significant changes over relatively short instructional units have yielded disappointing results (Authors 2014, 2016). In the context of relatively short-duration curriculum implementations, a student begins the lesson with a certain level of individual interest. This affects the ability of the curriculum and instructor to trigger situational interest through an appeal to students' perceptions of utility value, task interest, and success expectancy (Schechter et al. 2011).

Individual interest changes due to repeated experiences over semesters or years—hence it makes sense to position individual interest as an outcome of situational interest in these contexts. However, in shorter-duration instructional units, dispositional characteristics of the learner influence the ability of the learning environment to trigger situational interest (Renninger & Bachrach, 2015). Renninger and Bachrach also suggested that the process of triggering is complex and dynamic as multiple triggers may be co-occurring and learners' responses to triggers may also vary, depending on learners' characteristics. Individual interest, as a dispositional characteristic, plays an important role in learners' openness to explore and learn. Particularly, individuals with positive dispositions tend to be responsive to the learning environment through engaging in course activities and instructional conversation. For example, Durik and Harackiewicz (2007) found that situational interest was influenced positively by individual interest in a mathematics learning context. They also found that individual interest mediates the effect of situational factors (i.e., catch and hold) on situational interest, in a way that learners with high individual interest in math are ready to enter a more developed phase of situational interest (hold), in which learners make a deeper and more personal level of meaning to the math learning. Situational interest was also examined as an outcome of teacher characteristics in the literature. Rotgans and Schmidt (2001) have found that students supported by teachers with higher levels of cognitive congruence reported higher levels of situational interest. In addition, once situational interest is triggered, it has been found to be relatively stable across an instructional period (Rotgans & Schmidt, 2011). In sum, students with individual interest in a particular topic are more likely to devote focused attention, persevere through challenges, and enjoy their involvement in classroom tasks than individual without such interest; hence it makes sense to suggest that situational interest is an outcome of individual interest, and that situational interest may ultimately support student engagement in tasks (Renninger & Bachrach, 2015), with the ultimate outcome of learning.

The Connection between Student Interest, Prior Knowledge, and Learning

The positive connection between what students know and their levels of interest has long been recognized (Alexander, Kulikowich, & Jetton, 1994). However, much research and debate has gone into the structure of the causality. Students with greater prior knowledge of a subject tend to be more interested in that subject (Alexander, et al. 1997). However, Rotgans and Schmidt (2011) found that this knowledge effect applies more to individual than situational interest. In a study of college students, Harackiewicz, Barron, Tauer, and Elliot (2002) found that students' choice of a major depended upon perceived relevance of the knowledge gained in introductory courses, as opposed to the extent to which they enjoyed the lectures. A finer-grained study on college students by Durik and Matazarro (2009) found that interest increased with task complexity in students with high domain knowledge, but decreased with task complexity in students with low domain knowledge. These patterns make sense given research showing that people who are more intelligent or knowledgeable are more open to new learning experiences (Silvia & Sanders, 2010). Students who know less about a topic are less likely to see the inherent value of learning experiences, or even fear these experiences (Zeidner, Roberts, & Matthews, 2008), and are therefore less likely to set achievement goals and engage in learning activities

(Ainley, 2006). This openness to new experiences and the inherent drive to set goals are manifestations of individual interest (Hidi et al., 2002).

As it makes sense to posit that students who know more about a topic may exhibit a favorable disposition toward engaging in that topic, it also makes sense to hypothesize that students who are more interested in a topic will likely learn more in the context of instruction around that topic (Schiefele, 2001). Empirically, Schiefele (1998) and Ainley et al. (2002) found a moderate correlation between individual interest and academic performance. Hidi et al. (2002) argue that interest supports learning through the mediation of self-efficacy, while Harackiewicz (2007) suggests that engaged behavior may be the responsible mediator, further arguing that low interest can reduce persistence and performance significantly. Greene (2015) suggests a mediating effect of engagement in thought; that mastery and learning goals facilitate deep cognitive engagement, which ultimately leads to achievement. Similar arguments for the mediation of engagement in feeling and motivation are put forth by Pekrun and Linnenbrink-Garcia (2012) and Glynn et al. (2007), respectively. Given that engagement of student's feelings and motivation both depend on a student's interest in his/her learning environment, the argument for a connection between interest and learning follows.

Research on Interest in Health Sciences Contexts

There is a small amount of research directed at understanding the connection between learning and interest in health science curricular contexts. Low interest in health care was found to significantly decrease middle school students' motivation to learn from health-related curricula (Brown, Teufel, & Birch, 2006). Descriptive survey work with middle school students showed that middle school students' perceptions of a nursing career fell short of ideal in terms of autonomy, respect, pay, and busyness (Cohen, Palumbo, Rambur, & Mongeon, 2004). To the end of overcoming these non-ideal perceptions, Todaro, Washington, Boekeloo, Gilchrist, and Wang (2013) found that high school students' interest in health careers tends to be developed and supported by personal experiences participating in the care of others or oneself. The efficacy of a hands-on educational program in increasing both interest in pharmacy careers and knowledge of these careers was demonstrated at the middle school level by Goldsmith, Tran, and Tran (2014). Further, the importance of controlling for student interest in evaluation models for curricular impact has been documented in a game-based biotechnology intervention at the high school level (Authors, 2015). In summary, although some work has focused on understanding how various interventions support interest, we have yet to explore an actual process by which health sciences curricula can capitalize on students' interest to support learning.

Purpose of the Research

We explore the connections between three domains: individual interest, situational interest, and content learning, in the context of a short-duration health science intervention at the middle school level. Prior work suggests that individual interest, though difficult to change, can support learning in the classroom through motivational factors (Perkins & Salomon, 2012), and further helps make students more open to new experiences, indicating that situational interest may also play a role in helping a student with a positive

disposition learn (Hidi et al. 2002). Since the exploration of these relationships necessitates an appropriate framework, we first synthesize our current understandings into a single conceptual framework and then utilize it to address the following questions:

1. How does individual interest coming into a class activity focused on active learning influence students' situational interest?
2. How does individual interest influence what students learn from the activities?
3. How do students' situational interest relative to the classroom environment and the teacher's instruction influence what they learn from the activities?

Methods

Context and Participants

We collected data through pre- and post-tests before and after a two-week middle school-level instructional sequence focusing on light and vision. The assessments were administered by the classroom teachers as part of their instruction and de-identified data from these assessments were used for analysis. In total, 11 teachers from six Midwestern United States schools participated in the study. Eight hundred-eleven (out of 1,093 total) middle school (grade 7 and 8; age 12–14) students completed our assessments (Table 1). The participating schools were diverse in terms of size (71–816 students), minority enrollment (0–85%), and socioeconomic status of the student body (37–99% of students on free or reduced lunch).

Four hundred fourteen (51%) of these students reported male gender, and 365 (45%) reported female. Thirty-two students (4%) chose not to report their gender. Four hundred and six (50%) of students reported having a parent or relative who works in a health care profession, and 730 (94%) of the students reported that they planned on pursuing higher education after high school.

Assessments were administered prior to and immediately after completing a program of inquiry activities our team developed in collaboration with the teachers participating in the study. These curricula were an outcome of the project goal of developing teaching curriculum boxes that could be mailed conveniently to schools in under-resourced or remote regions that may not have access to materials conducive to active science learning. Activities and materials within the boxes were aligned with our state's science education standards so that the contents could fit within the traditional school curriculum. The data in this study were derived from the evaluation of a teaching curriculum box called "EyeInABox", designed to increase student's knowledge about light, color, vision and awareness of science and health careers. Intervention materials included a variety of exploration-based activities, such as properties of light and color (electromagnetic radiation) and how it is perceived by living organisms, the opportunity to dissect a cow eye, and materials relating to visual impairment, its correction, and the evolution of the visual systems. Exploration of visual impairments included the Braille alphabet and coping skills, and reading and discussion of individuals who are blind and how they cope with blindness. Materials relating to optics included activities with mirrors and subsequent study of the role of the visual cortex in

processing information collected by the eye. Students explored the evolution of the visual system in the context of reading and viewing videos about different organisms, from the simple layer of photoreceptors on planaria to the pinhole vision system of the nautilus to vertebrates who have a flexible lens comparable to that of humans. This facilitated the introduction of evolution by natural selection. We direct readers with an interest in learning more about this curriculum to the EyeInABox Teachers Guide (Supplementary Materials).

Basic Model for the Relationship between Interest, Prior Knowledge, and Learning

Individual interest is influenced by prior knowledge (i.e. Alexander, 1992; Silvia & Sanders, 2010), but there is little direct connection between prior knowledge and situational interest (Rotgans & Schmidt, 2011). Further, self-efficacy (Hidi, Berndorff & Ainley, 2002), engaged behavior (Harackiewicz, 2007), cognitive engagement (Greene, 2015), engagement of feeling (Pekrun & Linnenbrink-Garcia, 2012), motivation (Glynn et al. 2007) and goal setting (Ainley, 2006) are among the actionable mediating factors by which the psychological state of interest can lead to learning. Since a learner's individual interest provides a starting point in the process of triggering situational interest, and since factors like motivation and engagement are largely situation-specific (Hidi et al. 2002), it makes sense to hypothesize that the effect of individual interest on learning gains within a specific classroom experience would be mediated through a student's situational interest. Our conceptual model derived from the above reasoning is diagrammed in Figure 1.

Before discussing how we go about evaluating and applying this model to our evaluation, we would like to acknowledge its static nature at the outset. This should not be implied to mean that we do not expect interest to change; rather, use of Figure 1 makes the assumptions that (1) how these students express their individual interest is not likely to change significantly in two school weeks and (2) that relationships between individual interest, situational interest and conceptual knowledge are not likely to vary significantly between grades 7 and 8 in comparison with the other student-level variation that exists within these grades.

Evaluation Model and Instrumentation

Our framework (Figure 1) necessitated precise measures of individual interest, situational interest, and knowledge about light and vision. To assess individual interest, we used the Rasch-validated Assessment of Interest in Medicine and Science (AIMS) (Authors, 2016), to measure individual interest at three different levels of generalization: interest in science ($\alpha_{pre}=0.88$; $\alpha_{post}=0.89$), interest in health care ($\alpha_{pre}=0.91$; $\alpha_{post}=0.93$), and interest in vision care ($\alpha_{pre}=0.87$; $\alpha_{post}=0.89$). Integrating these three levels of interest into the framework (Figure 1) fits with evidence that individual interest is not a singular psychological state, but rather a network of related states (Ainley, Hidi, & Berndorff, 2002). If students exhibit individual interest in a specific domain, they are likely to also exhibit interest in related domains. Since topic interest is a specific form of individual interest (Schiefele, 1996), it makes sense in the disciplinary context of this study to model individual interest in vision care as a supporting factor in individual interest in health care, which themselves are supporting factors in individual interest in science (Figure 2).

In this study, we extended the AIMS to address situational interest. As with individual interest, it was important to operationalize situational interest in a way that was meaningful toward providing information about the process by which individual interest may support learning. In a school setting, situational interest is created first through the composition of the lesson itself which includes the content being taught and the arrangement of activities, and then through the teacher's presentation of the lesson which includes his/her ability to engage students in the activities (Krapp, 2002; Hoffmann, 2002). Indeed, that situational interest, once triggered, must be maintained by the instructor (Hidi & Renninger, 2006). Rotgans and Schmidt (2011) found that cognitive congruence—the ability of a teacher to explain topics using ideas, concepts, and terminology that students can understand—is the most important predictor for sustaining situational interest. These findings suggest collectively that situational interest is best defined by two constructs: (1) interest in classroom curricula/lessons, and (2) interest in the teacher's presentation of these, and further that (1) should precede (2) in the sequence between individual interest and learning (Figure 2). In our assessment, we therefore measured situational interest two-dimensionally: (1) interest in the classroom environment ($\alpha_{pre} = 0.73$; $\alpha_{post} = 0.79$), and (2) interest in the teacher's instruction ($\alpha_{pre} = 0.87$; $\alpha_{post} = 0.88$). Wording structures for the items measuring situational interest parallel many of those used in the Science Interest Scale (Lamb, Annetta, Meldrum, & Vallett, 2012). All items were scored along an ordinal 4-level Likert scale (SD=0, D=1, A=2, or SA=3).

To assess understanding of concepts related to light and vision over the instructional period, we developed the *Health Literacy in Vision Care Assessment*. This included 21 multiple choice items ($\alpha_{pre} = 0.58$; $\alpha_{post} = 0.66$) addressing the following: properties of electromagnetic radiation, light and color, optics, anatomy and function of the vertebrate eye, evolution of visual systems, and vision deficits including ways to help cope with them. Items were scored dichotomously (correct = 1, incorrect = 0). The reliability values for this assessment are moderate due to the variety of content assessed, but nonetheless exceed What Works Clearinghouse (2014) internal consistency requirements.

We found that student learning was consistently positive ($\overline{gain} = 0.45$ logits, $SD_{gain} = 0.90$ logits, $t_{(810)} = 14.5$, $p < 0.001$, Cohen's $D = 0.54$), but that changes in interest through the instructional period were negligible (Authors., 2016). This indicates the expected result that individual interest did not change over a short time (Authors 2014), and that the intervention did not significantly change students' perception of the teacher's instruction or the classroom activities.

We used students' pre-test scores on the AIMS to obtain students' individual interest when entering the 10-day intervention, which is consistent with the positioning of individual interest as a starting point in the context of a relatively short instructional sequence (Hidi & Harackiewicz, 2000; Renninger & Bachrach, 2015). Since we were not just interested in whether situational interest was triggered, but more the extent to which it was maintained at the end of the instruction (i.e. Rotgans & Schmidt, 2011), post-test scores were used to measure the situational interest constructs. Finally, given learning as the target outcome, we used students' pre-post knowledge gains as a measure of content learning.

Data Analysis

Our analysis first consisted of a partial correlation analysis between each of the variables in the model, controlling for students' classrooms (ten level-2 dummies), so that we were able to evaluate the direct linear relationship between each variable individually independently of students' classrooms.

We used Confirmatory Factor Analysis (CFA) in MPlus7 (Muthen & Muthen, 2012) to confirm that the items measure their intended construct independently of the other constructs on the assessment. We tested this through a model assuming five latent variables (interest in science, health care, vision care, interest in the classroom environment, and teacher's instruction) and a simple structure, meaning that the items load onto a single dimension with no cross-loading (see Figure S1 in Supplementary Materials). The weighted least squares estimator (WLSMV) was used to estimate model parameters. The WLSMV was selected as it was appropriate when fitting a measurement model with ordinal indicators (Flora & Curran, 2004). We used the Pearson's chi-square, the normed chi-square, the comparative fit index (CFI), the Tucker-Lewis index (TLI), and the Root Mean Square Error of Approximation (RMSEA) as measures of model fit. Pearson's chi-square should be non-significant for a well-fitting model, indicating the covariance structure produced by the model is not significantly different than the actual covariance structure in the data. Given this criterion is overly conservative at the sample sizes used in this study, we took the ratio of chi-square to degrees of freedom (the normed chi-square). Schumacker and Lomax (2004) suggest a value of 5 or below as indicative of adequate fit while a value as low as 2 is suggested by Ullman (2001). In addition to the chi-square statistics, we used two relative fit indices (the CFI and TLI) and an absolute fit index (the RMSEA). A value of 0.90 or above for the CFI and TLI is often used as an indicator of a good-fitting model (Bentler, 1990). Models that fit the data well have an RMSEA of 0.05 and adequate models have an RMSEA of 0.08 (Millsap, 2011).

After determining the appropriate fit of the measurement model, we evaluated the strength of evidence our data provide in support of Figure 2 based on how well a structural model with the variables structured as laid out in Figure 2 (with the ten level-2 dummies) reproduces the covariance structure of the data. We used structural equation modeling in MPlus7 (Muthen & Muthen, 2012) to evaluate both direct and indirect effects of students' individual and situational interest on their learning in the context of the instructional unit. All the five latent variables and two observed variables (prior knowledge and knowledge gain) were entered into the SEM model simultaneously (Figure 3). We calculated standard errors and confidence intervals for each effect using non-parametric bootstrap distributions (Bollen & Stine, 1990) derived from resampling the data with replacement 10,000 times. The same goodness-of-fit indices described in the CFA analysis were also used to evaluate the structural model.

Structural equation modeling is a generalized statistical method that allows the researcher to evaluate multiple conceptual processes in a single statistical model (Norman & Streiner, 2003; Mueller, 1996; Wolfle, 1999; Graham, 2007), and is an extension of path analysis in that the measurement model (Figure S1) is nested within the structural model (Figure 3). Assumptions of SEM include that the distribution of the data is known, there is actual

association between the variables as the model suggests, there are no other plausible explanations (or confounding variables) outside of the model(s) specified, the direction of the sequence is specified correctly, and the causes precede the effects in time (Kline 2015).

While there are clearly many factors influencing students' interest and learning which are outside the scope of this study, our use of findings from an extensive literature base as a foundation for our analysis assists us in invoking the above assumptions with reasonable validity. This allowed us to evaluate reliably the strength of evidence the data provide for the model. This is not the first study to utilize structural equation modeling or path analysis as a medium for understanding how student interest is connected to motivational factors and student achievement (others include Ainley, Hidi, & Bernsdooff, 2002; Nieswandt, 2007; Hulleman, Durik, Schweigert, & Harackiewicz, 2008; Harackiewicz, 2008; Rotgans & Schmidt, 2011). However, this study is the first to use this method to evaluate the relationship between individual interest, situational interest, and actual knowledge gains in the context of a specific instructional unit.

Model Building

Assuming an acceptable model fit, we then used individual path coefficients to test the extent to which data support the direct and indirect effects proposed in Figure 2. Direct paths included the effects of positive reactions to the teacher's instruction on student's learning and the effect of individual interest on situational interest in the classroom environment. However, we were also interested in the indirect effects: individual interest on students' learning (mediated through situational interest) and situational interest in the classroom environment on students' learning (mediated through positive reactions to the teacher's instruction). Standardized path coefficients were evaluated at $\alpha = 0.05$ based on its non-parametric bootstrap distribution under the null hypothesis of no relationship. Beyond statistical significance, the practical significance is also of interest when evaluating the effects in our model. Although putting forth rules for qualitative interpretation of the magnitude to which a direct effect is present in the data may seem straightforward (Cohen, 1977; Keith, 1993), the actual importance of the effect is subjective and context-dependent. In the context of the educational sciences, Keith (1993) cautiously suggests that standardized path coefficients above 0.25 may be considered large, 0.15–0.25 moderate, 0.10–0.15 small, and below 0.10 negligible. Alas, a “large effect” between individual and situational interest may be expected and less important than a “small effect” between situational interest and knowledge. Further, these rules and other conventional effect size frameworks do not hold for indirect effects (Preacher & Kelley, 2011). We direct readers interested in the efficacy of the variables as mediators to our analysis of mediation and model interrogation within the Supplementary Materials.

Results

Correlational Analysis

We begin with a correlational analysis (controlling for classroom) between the variables of individual interest, situational interest, prior knowledge, and learning. The correlation coefficients in Table 2 represent a relatively complex, flexible model that entertains the

assumption that all of the individual constructs may have a direct effect on each other; hence no specific directionality is specified.

This analysis shows that individual interest in science is moderately correlated ($0.39 < r < 0.50$) with the other individual and situational interest constructs, has a lower but positive correlation with prior knowledge ($r = 0.22$), and has a small negative correlation with learning gains ($r = -0.072$). Prior knowledge has a small-to-negligible correlation with all of the additional interest constructs, and that with the exception of the negative relationship with individual interest in science, the correlations between the other interest constructs and learning gains are non-significant.

This analysis would appear to indicate that interest has very little relationship with learning, and the negative correlation could even be interpreted to indicate that individual interest inhibits learning. Such conclusions based on a correlation matrix, which specifies only direct effects, should be treated with caution. Not only does correlation not imply causation, but there exists extensive literature demonstrating that directional relationships between these constructs do exist (as specified in Figures 1 and 2).

Measurement Model

The measurement model included all the items used to measure individual (vision care, health care, and science) and situational interest (teacher's instruction and classroom activities). Absolute fit measures indicate adequate fit (RMSEA = 0.076) (Hu & Bentler, 1999, Millsap, 2011), and relative fit measures indicate good model fit (CFI = 0.925, TLI = 0.916) (Hu & Bentler, 1999), confirming the structure of the assessment as a measure of five unique dimensions of individual interest and situational interest. These values suggest a good fit between the predicted and observed data. Standardized parameters are presented in Figure S1 in Supplementary Materials.

Structural Model

Figure 3 consists of eight direct unidirectional effects, as opposed to the 21 direct effects modeled in our correlational analysis (Table 2). Our fit indices suggest that such an invocation of parsimony did not detract practically from our ability to explain the data. Further, mediation analysis through testing of more complex reasonable alternative models showed that additional paths added to the model were non-significant at the 95% confidence level (Supplementary Materials), warranting retention of the current model as a framework for testing of our research questions.

While the correlational structure produced by the model in Figure 3 was statistically different than that in Table 2 ($\chi^2_{(801)} = 2341.54$, $p < 0.001$), the normed chi-square value of 2.92 fell close to the relatively strict criterion of 2 for good fit (Ullman, 2001) and well below the comparatively liberal criterion of 5 proposed by Schumacker and Lomax (2005). Additional fit statistics indicate that the model explains the relationships between the constructs well. We calculated a CFI of 0.937 and a TLI of 0.930, both of which meet the criterion of 0.9 suggested by Bentler (1990). The RMSEA value of 0.049 falls below Millsap's (2011) criterion of 0.050 for good model fit.

RQ1: How does individual interest coming into a class activity focused on active learning influence students' situational interest?

We found that the effects of individual interest on situational interest (Table 3) were positive and highly significant. The standardized direct effect of individual interest in science and situational interest in the classroom activities was 0.61 (SE = 0.04, $Z = 16.55$, $p < 0.001$, 95% CI = 0.54–0.69). The indirect effect of individual interest in science on situational interest in the teacher's instruction, mediated through situational interest in the classroom activities, was 0.48 (SE = 0.04, $Z = 13.49$, $p < 0.001$, 95% CI = 0.41–0.55).

Individual interest in health care and vision care had smaller, but nonetheless positive, effects on situational interest (Table 3). Individual interest in health care, mediated through individual interest in science, had an indirect effect of 0.15 (SE = 0.03, $Z = 5.05$, $p < 0.001$, 95% CI = 0.09–0.21) on situational interest in the classroom activities. Through the mediation of both individual interest in science and situational interest in the classroom activities, an indirect effect of 0.12 (SE = 0.02, $Z = 4.29$, $p < 0.001$, 95% CI = 0.07–0.16) was found between individual interest in health care and situational interest in the teacher's instruction.

Individual interest in vision care had a total indirect effect of 0.30 (SE = 0.03, $Z = 10.51$, $p < 0.001$, 95% CI = 0.24–0.35) on situational interest in the classroom activities through the mediation of individual interest in health care and science, and a total indirect effect of 0.23 (SE = 0.03, $Z = 9.47$, $p < 0.001$, 95% CI = 0.18–0.28) on situational interest in the teachers' instruction, with situational interest in the classroom activities serving as the additional mediator (see Figure 3).

RQ2: How does individual interest influence what students learn from the activities?

We found that individual interest in learning science had a non-significant indirect effect of 0.04 (SE = 0.03, $Z = 1.46$, $p = 0.144$, 95% CI = –0.01–0.09) on knowledge gains. Similarly, individual interest in health care and vision care had non-significant total indirect effects of 0.01 (SE = 0.01, $Z = 1.36$, $p = 0.174$, 95% CI = –0.00–0.02) and 0.02 (SE = 0.01, $Z = 1.45$, $p = 0.143$, 95% CI = –0.01–0.04) on knowledge gains, respectively (Table 3).

RQ3: How do students' situational interest relative to the classroom environment and the teacher's instruction influence what they learn from the activities?

Situational interest in the teacher's instruction (Table 3) had a small yet significant direct effect of 0.08 (SE = 0.04, $Z = 2.10$, $p = 0.035$, 95% CI = –0.02–0.17) on knowledge gains. On the other hand, situational interest in the classroom activities had a non-significant indirect effect of 0.06 (SE = 0.04, $Z = 1.48$, $p = 0.139$, 95% CI = –0.20–0.14) on knowledge gains through the mediation of situational interest in the teacher's instruction.

Discussion

Previous studies illustrate that there are multiple affective factors including interest that support learning and achievement. However, these have focused primarily on high school and college students in the context of relatively long instructional durations on the order

of semesters, and have defined achievement with a single measure at a single point in time. This study is different in its positioning within a much more narrowly focused area (light, color and vision) and a short time duration (2 weeks) at the middle school level. To understand better the impact of student interest on learning, we believe this short duration and topic specificity provides an important contribution to the field. By its definition, both individual and situational interest can be highly topic- and environment-specific (Hidi et al. 2002), meaning that the specific context of this study permits us to tease out precise relationships between the different forms of student interest and their impact on learning at the middle school level. Further, the model we propose (Figures 2 and 3) is the first to suggest empirically that situational interest is triggered first through the classroom environment, and then through the teacher's presentation of the lesson (Krapp, 2002; Hoffmann, 2002), and to test this with data in an actual classroom context. Work on the development of individual interest over long durations suggests that situational interest across repeated experiences solidifies into individual interest (Hidi & Renninger, 2006), and our model permits understanding of how individual interest can support learning within timeframes where it is unrealistic to expect significant changes in individual interest to occur (Authors, 2014).

Evidence Supporting the Conceptual Model, and Applications

We expected to see positive effects given prior work supporting positive relationships between interest and academic achievement (i.e. Nieswandt, 2007). Rather, our correlational analysis suggested that student interest had non-significant, or even negative, effects on learning. Upon analyzing these data with a conceptual model based on findings from the literature (Figure 2), we found that student individual interest had a non-significant indirect effect on learning through situational interest. Although situational interest in teacher's instruction supports learning with a small effect, we did not find that situational interest in classroom activities support learning indirectly through situational interest in the teacher's instruction.

From a statistical perspective, we observed a weak relationship between situational interest in teacher's instruction and knowledge gains. To observe a mediation effect, the mediator(s) need to have a strong correlation with the target endogenous variable. Given that the other effects in the model are large, it is likely that the weak link between situational interest in teacher's instruction and knowledge gain resulted in the non-significant impact between individual interest and learning as well as between situational interest in classroom activity and learning. This suggests that other factors unmeasured in this study, such as attention, goals, or engagement, mediate the impact of interest on learning.

For example, Ainley (2006) and Hidi et al. (2002) suggest that goal setting and openness to new experiences are important actions that are driven by student interest and ultimately support learning while Harackiewicz (2007) suggests that self-efficacy is a mediator between interest and learning. Cognitive engagement may also serve as an effective mediator (Greene, 2015). Indeed, a study by Singh, Granville, and Dika (2002) found that students' academic engagement mediated the effect of interest on learning among middle school students in the context of math and science. In future studies utilizing this model, precise

measures of motivation, engagement, self-efficacy, or goal orientation will enhance detection of stronger and significant indirect effects of interest on learning.

As illustrated above, despite the importance of capitalizing on student interest toward facilitation of learning, we would like to emphasize that interest is not the only thing that affects learning. We also understand that prior knowledge affects what students learn. The direct effect of prior knowledge can be explained in two ways: (1) that students with more knowledge will get more out of the instruction, or (2) that students who know more have less to learn from the instruction. The negative direct effect of prior knowledge on learning in Figure 3 indicates that the second explanation best describes the students in our study. Students scoring higher on the pre-test simply had less to improve and therefore experienced more modest gains. It is not clear whether this effect is due to the instruction or to the fact that our test was too easy for some students—hence we consider this a study limitation.

We nonetheless observed that prior knowledge improved individual and situational interest. Students with higher prior knowledge tended to have higher levels of individual interest in science (Figure 2) which is likely due to students knowing more about a topic and therefore being less fearful of it; thus they perceive a greater likelihood that it will be rewarding to study (Panksepp, 2003).

Limitations and Future Directions

We frame the discussion of future directions in terms of the study's limitations. Foremost, our analysis focused on interest exclusively: the effect of individual and situational interest on learning in the context of a specific short-duration intervention targeted towards middle school students. To expand our conceptual model, future studies should consider including engagement as a mediator between situational interest and learning, as the mediating role of engagement has been suggested in the previous literature—this serves as a bridge in the causal relationship between how students feel and the ultimate learning gain they achieve (Reeve, 2012).

As it stands, our conceptual model may be applicable to a wide range of ages and learning contexts, but the generalizability of our specific effects may be context-dependent based on students' grade levels and the target content areas. Given that student interest involves inclination (affect) that gets integrated with specific content (cognition) over time, it would make sense that younger students may manifest their interest differently from older students who may express their interest from a more cognitive perspective (Nolen, Horn, & Ward, 2015). In this sense, students' ages or levels in school may moderate the relationships in Figure 3. For example, if our framework were applied to high school and college students, we might expect stronger relationships between prior knowledge and interest. On the other hand, the relationship between prior knowledge and interest may be much less in young children who have less prior knowledge and therefore less of a cognitive foundation on which to support their interest.

Our findings can be generalized to similar interventions at the middle school level, but if this model were applied in the context of a different intervention, the relationships may be different depending upon students' familiarity with the content, their initial levels of interest,

and how the instructional materials were implemented. We would like to see this framework tested with a variety of academic levels and contexts toward a broader understanding of how interest can facilitate learning.

Finally, we would like to point out that we specified our framework to represent the effect of student interest on learning within a short duration of instruction. In the current study, we used students' post-test of situational interest to measure the extent to which it was maintained at the end of the instruction. In the context of tablet-mediated biology learning, Jung, Zimmerman, and Land (2017) found that when triggered situational interest is maintained and encouraged, students continue to stay cognitively and emotionally engaged in learning. We went into the study with the assumption that situational interest was maintained throughout the 10-day period, but do not have sufficient data to support this. It is possible that the weak link between situational interest in teacher's instruction and learning gains may result partially from situational interest not being maintained consistently throughout the instructional period. In future work, one may wish to measure situational interest multiple times to test the extent to which it was maintained, although this would be prohibitively resource intensive in many contexts. An alternative approach would be to shorten the duration of instruction further, allowing measurement of situational interest within even more specific instructional contexts to see how our framework applies as specific instructional topics or activities become increasingly fine-grained. Toward following students across a timeframe sufficient to see enduring changes in individual interest, the effect of repeated triggering and maintenance of situational interest, and its effect on subsequent changes in individual interest (Hidi & Renninger, 2006) would need to be specified. In this sense, our model represents a single iteration in a cycle of student development where specific experiences (situational interest) integrate into a dispositional tendency (individual interest) which in turn influences subsequent experiences (situational interest) (Hidi & Renninger, 2006). We have specified and measured how interest can lead to learning within a single cycle in our instructional context, but it would be interesting to explore how this applies to even shorter time durations, and within a dynamic framework, addressing how the effect of interest on learning changes over longer timeframes where significant changes in individual interest are occurring.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.
Hypothesized relationship between individual interest, situational interest, and learning.

Figure 2.

An adaptation of our conceptual framework in Figure 1 to the context of our instructional context.

Figure 3.

Evaluation model quantifying the effect of student interest on learning in the context of the Eye in a Box instructional unit. Standardized path coefficients (standard error) are reported. Level-2 blocking effects (classrooms) are not shown in the diagram. All direct paths shown in the diagram are statistically significant at the 0.05 alpha level.

Table 1.

Sample Characteristics

Student Characteristics (N = 811)	N (%)
Gender	
Male	414 (51%)
Female	365 (45%)
Did not report	32 (4%)
Parents or relative works in a health care profession	
Yes	406 (50%)
No	405 (50%)
Plan to attend college	
Yes	730 (90%)
No	81 (10%)

School Characteristic	School 1	School 3	School 4	School 5	School 6
Minority Enrollment	0%	61%	85%	36%	34%
Free or Reduced Lunch	48%	50%	49%	37%	99%
Total Students	71	816	771	747	316

Note: All students are in middle school (grade 7 and 8; age 12 – 14).

Table 2

Correlation matrix of Rasch measures for the individual interest, situational interest, prior knowledge, and learning constructs.

CONSTRUCT ^a	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Science Interest							
(2) Health Care Interest	0.46 ^{**}						
(3) Vision Care Interest	0.45 ^{**}	0.59 ^{**}					
(4) Classroom Interest	0.50 ^{**}	0.27 ^{**}	0.27 ^{**}				
(5) Teacher Interest	0.39 ^{**}	0.23 ^{**}	0.21 ^{**}	0.66 ^{**}			
(6) Prior Knowledge	0.22 ^{**}	0.09 [*]	0.05	0.11 ^{**}	0.11 ^{**}		
(7) Learning Gains	-0.07 [*]	0.03	-0.06	0.01	0.06	-0.36 ^{**}	
Rasch Reliability	0.88	0.91	0.86	0.78	0.77	0.59	0.66

*
α=0.05,

**
α=0.01

^aCorrelations account for level-2 blocking variables (classrooms)

Table 3.

Standardized effects of individual interest on situation interest and learning gains by research questions.

	<i>B</i>	<i>SE B</i>	<i>Z</i>
RQ1: Effects of individual interest on situational interest			
Science Interest			
<i>Science Interest → Classroom Interest</i>	0.61	0.04	16.55
<i>Science Interest → Classroom Interest → Teacher Interest</i>	0.48	0.04	13.49
Health Care Interest			
<i>Health Care Interest → Science Interest → Classroom Interest</i>	0.15	0.03	5.05
<i>Health Care Interest → Science Interest → Classroom Interest → Teacher Interest</i>	0.12	0.02	4.92
Vision Care Interest			
<i>Vision Care interest → Classroom Interest (sum of indirect effects)</i>	0.30	0.03	10.51
<i>Vision Care Interest → Teacher Interest (sum of indirect effects)</i>	0.23	0.03	9.47
RQ2: Effects of individual interest on learning gains			
Science Interest			
<i>Science Interest → Classroom Interest → Teacher Interest → Learning Gains</i>	0.04	0.03	1.46
Health Care Interest			
<i>Health Care Interest → Science Interest → Classroom Interest → Teacher Interest → Learning Gains</i>	0.01	0.01	1.36
Vision Care Interest			
<i>Vision Care Interest → Learning Gains (sum of indirect effects)</i>	0.02	0.01	1.47
RQ3: Effects of situational interest on learning gains			
Teacher Interest			
<i>Teacher Interest → Learning Gains</i>	0.08	0.04	2.11
Classroom Interest			
<i>Classroom Interest → Teacher Interest → Learning Gains</i>	0.06	0.04	1.48

Note: $N = 811$. Significant coefficients ($p < .05$) are in bold