JOURNAL OF RESEARCH IN SCIENCE TEACHING VOL. 49, NO. 4, PP. 515–537 (2012)

Research Article

Activity Matters: Understanding Student Interest in School Science

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Received 11 September 2010; Accepted 14 January 2012

Abstract: A genuine interest in science is an important part of scientific literacy, and thus a critical goal for science education. Recent studies, however, have found that school science has not been effective in meeting this goal, an important reason for which is the lack of knowledge about what makes science interesting (or not) to the students. Using instructional episodes as the unit of analysis, this study investigated the effects of learning environment elements (content topic, activity, and learning goal) on student interest in science. The findings indicated that when judging the interestingness of an instructional episode, students focused primarily on the form of activity rather than content topic and learning goal. Activities that were "hands-on" in nature and allowed for engagement with technology elicited higher interest. This study highlights the need to place more emphasis on the role of activity in constructing interesting learning environments, and in the mean time, suggests that student science interest could be improved by making changes to relatively easy-to-manipulate aspects of learning environments, such as those examined in the study. © 2012 Wiley Periodicals, Inc. J Res Sci Teach 49: 515–537, 2012

Keywords: interest; science education; activity; learning environment elements

A genuine interest in science is not only an obvious prerequisite for a career as a scientist, but also a necessary component of scientific literacy (Rutherford & Ahlgren, 1991). Given the importance of science interest, it is disconcerting that many researchers have observed the problem of students becoming uninterested in and unmotivated to learn science at a young age (Anderman & Maehr, 1994; Hidi & Harackiewicz, 2000; Renninger & Hidi, 2011; Schmidt et al., 2001; Yager & Yager, 1985). This phenomenon is particularly pronounced in the school context, where students who hold a positive view of the role of science in society express negative feelings about science in school (Sjøberg & Schreiner, 2006). With much evidence supporting the positive impact of interest on a variety of learning outcomes (Krapp, Hidi, & Renninger, 1992; Schiefele, Krapp, & Winteler, 1992), it is reasonable to suggest that the lack of interest among young students not only threatens the production of the next generation of scientists, but more importantly, impedes students from becoming scientifically literate citizens, as they are unlikely or even unable to engage with important science-related societal issues.

Sources of Science Interest

Faced with this problem, researchers have sought to identify sources of student interest, or ways of fostering interest. A rich body of literature has examined features of text that

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Additional Supporting Information may be found in the online version of this article.

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DOI 10.1002/tea.21010

makes it interesting to readers. The focus on text-based interest is motivated by the fact that text is arguably the most common medium for information delivery, and by the observed strong positive correlations between interest and text learning (Schiefele, 1999; Silvia, 2006). Text features that have been reported to affect readers' interest include the content's level of unexpectedness or suspensefulness (Hidi, 2001; Hidi & Baird, 1986; Iran-Nejad, 1987), the inclusion of characters with which the reader can identify (Hidi, 1990, 2001; Krapp et al., 1992) or issues that are personally relevant (Schraw, Flowerday, & Lehman, 2001), as well as content-bound text characteristics such as text coherence (Schraw & Lehman, 2001), intensity (Hidi, 1990, 2001), concreteness (Wade, 1992), and vividness (Schraw, Bruning, & Svoboda, 1995). More closely related to science learning, Hidi and Anderson (1992) reported a study that examined science and social science textbooks used in Canadian schools, and found that texts categorized as narrative stories were considered more interesting than those labeled as expository (dealing with facts, explanations, descriptions, and/or instructions) or mixed.

Aside from text features, some researchers have attempted to identify specific science topics that young people perceive as interesting. For instance, Baram-Tsabari and Yarden (2005) examined the questions (primarily in the domain of science) Israeli children sent to a popular children's TV show that provided answers to their questions (e.g., "if you go on a diet, where does the fat go?"). The researchers concluded that topics of biology, technology and astrophysics were of high interest to the 9- to 12-year-old children. Dawson (2000) asked seventh-grade students in Australia to indicate the interestingness of 77 science topics (e.g., "earthquakes") representing a broad range of scientific domains, and identified a set of topics that were most popular for these students. Similarly, as part of the large-scale international study ROSE (Relevance of Science Education, Schreiner & Sjøberg, 2004), Jenkins and Nelson (2005) surveyed a group of 14- and 15-year-old students in England, and identified a list of science topics that the students most and least wanted to learn.

Other researchers proposed that students came into school with strong innate interest in science, and the decline of their interest stems from the way science is taught (Krajcik, Czerniak, & Berger, 2003). The studies by Mitchell (1993) and Palmer (2009) spoke to this issue by examining students' interest as they experienced math and science lessons in the classroom. Specifically, Mitchell (1993) used focus groups and self-report questionnaires to identify two main sources of interest for students in high school math classrooms. First, students found content that they perceived as personally "meaningful" — topics that were important in or related to their daily lives — to be interesting. Second, the form of activities (i.e., the use of group work, computers, puzzles) through which learning took place also played an important role in influencing student interest. Palmer (2009), on the other hand, investigated Grade 9 Australian students' interest in an inquiry-based science lesson. Using a one-item measure, Palmer documented students' interest immediately after each phase of the lesson (demonstration, proposal, experiment, and report), and found that student interest was much higher during the experiment and demonstration phase than during the other two phases. A group interview was also conducted at the end of the lesson to identify sources of interest, and three main sources were identified — novelty, autonomy, and social involvement. The findings of these studies echo the anticipated advantages of inquiry-based or project-based curricula that engage students in "real, meaningful problems that are important to them" (Krajcik & Blumenfeld, 2006, p.318). The idea is that having students actively participate in authentic activities similar to those in which professionals participate (DeBoer, 1991; Edelson, Gordin, & Pea, 1999; Krajcik et al., 1998, 2003) holds great potential for promoting student interest and engagement (Blumenfeld, Kempler, & Krajcik, 2006).

In the present study, we consider the question of student interest from the perspective of the complex nature of science classrooms. In a single lesson, students typically interact with several elements (e.g., topic, activity) of the learning environment they are in. Thus their interest (or lack of it) might well be a reaction to a combination of (some or all) elements. This means that research examining only individual elements might not do justice to the kind of complexity that governs student interest in actual classrooms. That is, for example, while the identification of "interesting topics" might help teachers choose content topics that students are more motivated to learn, it might not be an optimum strategy to build a science curriculum solely on the basis of students' expressed interests (Jenkins & Nelson, 2005). Even favorite topics are not encountered in isolation, students' perceptions of a topic's interestingness are often mediated by the way it is taught (Swarat, Ortony, & Daniels, 2006). Similarly, information regarding activities that are considered authentic, though offering useful guidelines on how to structure an interesting lesson, only describes one slice of student experience in their science classrooms.

Therefore, in the present study, we attempted to take a more holistic approach and examine the effects of three learning environment elements — content topic, activity, and learning goal — on student interest in science. Before we discuss the specific study details, however, it is necessary to first clarify what we mean by interest.

Definitional Issues

Interest (or interesting) is a familiar term frequently used in daily conversations. However, depending on the context, people assign different meanings to the term, examples of which include curiosity, enjoyment, and motivation (Silvia, 2006; Valsiner, 1992). The "slippery" nature of the term may explain why there seems to be no consensus on *a* definition of interest among researchers. As a result, the construct "interest" examined in existing studies often bears different meanings that reflect the theoretical perspectives of the researchers (Renninger & Hidi, 2011).

For instance, Hidi and Renninger (2006) defined interest as "a motivational variable" referring to "the psychological state of engaging or the predisposition to reengage with particular classes of objects, events, or ideas over time" (p.112). Deci (1992) stated: "In self-determination theory, interest is conceptualized as the core affect of the self — the affect that relates one's self to activities that provide the type of novelty, challenge, or aesthetic appeal that one desired at the time" (p.45). Meanwhile, Schiefele and his coworkers defined interest as "a content-specific motivational characteristic" (Schiefele, 1992, p.299) or "specific preference for particular subject areas" (Schiefele et al., 1992, p.184). Schraw and Lehman (2001) viewed interest as "liking and willful engagement in a cognitive activity" (p.23), whereas Edelson and Joseph (2003) defined it in the context of curriculum design as "a motivation to engage with a topic (e.g., dinosaurs) or an activity (e.g., photography)" (p.26). Dewey (1913), on the other hand, suggested that the person and the object could not be discussed separately when speaking of interest. In his view, true interest is one's *identification* with and *absorption* in certain objects—"Genuine interest is the accompaniment of the identification, through action, of the self with some object or idea, because of the necessity of that object or idea for the maintenance of a self-initiated activity" (p.14).

It is easy to see from these definitions that the boundary between interest and other psychological constructs such as motivation and engagement is rather vague. One suggested characteristic that separates interest from other constructs is its object-, content-, or domain-specific nature: "Most conceptualizations (of interest) include notions of knowledge and/or reference value and refer to a person's interaction with a *specific* class of tasks, objects, events, or ideas. Such specificity distinguishes individual interests from other psychological concepts such as intrinsic motivation, attention, arousal, curiosity, and exploration" (Krapp et al., 1992, p.8). Similarly, Renninger (2000, as cited in Wade, 2001) suggested that the outcomes of individual interest tend to be linked to particularly person-subject or -content relations over time, whereas the outcomes of intrinsic motivation tend to apply more generally to a person's behavior. Object specificity aside, most interest and motivation researchers seem to agree that these two constructs are mutually related (Hidi & Harackiewicz, 2000; Renninger & Hidi, 2011): interest researchers tend to view interest as the precondition for intrinsic motivation and mastery goal orientation, whereas the motivation researchers, particularly goal orientation scholars, often see interest as the outcome of mastery goal adoption. Another commonly used proxy for interest, particularly in classroom learning situations, is engagement — active involvement in learning and academic tasks, including behaviors such as concentration, attention, asking questions and contributing to class discussion (Fredricks, Blumenfeld, & Paris, 2004). However, the relationship between interest and engagement is inconclusive. While it is reasonable to anticipate strong interest manifests itself as high level of engagement, some studies have shown that such a correlation is not always transparent — Ainley (2004) and Swarat (2005) reported that students who appeared to be off-task were actually highly interested in the topic, and students who were judged by observers to be actively engaged were not even thinking about the material (Peterson, Swing, Stark, & Waas, 1984).

Despite the ambiguity on *a* definition of interest, the distinction between two forms of interest — *individual* and *situational* interest — has been widely accepted by researchers (e.g., Ainley, Hidi & Berndoff, 2002; Hidi, 1990, 2001; Hidi & Baird, 1986; Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006; Krapp et al., 1992; Schiefele, 1992; Silvia, 2006). *Individual interest* refers to an individual's disposition towards a certain domain — "a person's relatively enduring predisposition to reengage particular content over time" (Hidi & Renninger, 2006, p.113), or "a relatively enduring preference for certain topics, subject areas, or activities" (Schiefele, 1992, p.152). Individual interest develops slowly over time and tends to be long lasting. It is often accompanied by positive affect and persistence, and tends to lead to increased knowledge. Over time, individual interest may be integrated into the person's value system and become one of its basic components. Therefore, it is suggested that people carry with them a set of individual interests, which influence how they interact with various objects. When people with certain individual interest encounter a situation that matches the particular interest, their individual interest is *actualized* — referred to as *actualized individual interest* by some researchers (e.g., Schraw & Lehman, 2001). In contrast, *situational interest* refers to a temporary state of interest elicited by certain aspects of the environment (e.g., object, activity, context, etc.) — "focused attention and the affective reaction that is triggered in the moment by environmental stimuli" (Hidi & Renninger, 2006, p.113). By definition, situational interest is often short-lived. It can be associated with both positive (e.g., enjoyment of working on a puzzle) or negative (e.g., disgust when dissecting a snake) affect, and may or may not have an impact on the person's knowledge or value system. Only when situational interest is maintained over time, or when it occurs repeatedly in response to the same stimuli, does it possibly lead to long-term interest, increased knowledge, changes in values, and consistent positive feelings.

While the distinction that individual interest and situational interest attempt to capture — one's disposition versus momentary state of interest — is reasonable and has generally served the field well, this model has its limitations. As Silvia (2006) pointed out, the distinction between *actualized individual interest* and *situational interest*, though sounding plausible in theory, remains untested, and is often not distinguished in empirical studies. As both types of interest are triggered by certain aspects of the environment, it is difficult (if not impossible) to know, when a person becomes interested in a situation, whether the interest is simply a short-lived reaction, or an activation of his or her stable interest. Furthermore, these terms do not reflect the fact that for a person to feel interested in something requires a contribution from *both* the individual and the situation, with individual interest emphasizing interest as an inherent, unchangeable entity within an individual, and situational interest ignoring the role of personal appraisal or interpretation of the situation in the generation of interest. Therefore, Silvia proposed an alternative way of framing the individual-situation interest distinction—*interest* versus *interests*. *Interest* here describes the psychological state of interest, despite whether it is an actualized state of one's stable interest, or a momentary reaction elicited by the environment; and *interests* replaces individual interest to refer to one's enduring disposition towards certain domains.

We adopted the conceptual distinction between *interest* and *interests* in our study. For science educators, both *interest* and *interests* are of great importance. On the one hand, school science bears the responsibility of helping students develop long-term stable interests in science; On the other hand, science classes should be able to elicit short-term interest in students so that they are motivated to learn the materials at hand (Hidi & Harackiewicz, 2000). We chose to focus on *interest* in this study because of its ease of generation or manipulation by educators, and the operational and methodological difficulties in identifying and measuring *interests* (see Azevedo, 2004 for example). This choice is also motivated by the assumption that repeated occurrence of *interest* will lead to *interests*, either through repeated exposure (Hidi & Renninger, 2006; Hoffman, 2002) or through a process that is more reflective in nature (Silvia, 2006).

Study Overview

The present study examines the individual and interactive effects of three learning environment elements on student interest in science — the *content topic* to be learned (e.g., food chain), the *activity* through which the particular content is learned (e.g., group discussion), and the *goal* of learning the particular content (e.g., to appreciate the relevance of a scientific phenomenon to one's life). There are, of course, numerous elements that could influence student interest, but we decided to focus on these three because they are the major and essential components of a science lesson, and collectively can provide a good portrait of the classroom environment. The choice of these elements is also supported by findings of Haussler and colleagues concerning the dimensions of student interest in physics (Haussler, 1987; Haussler, Hoffman, Langeheine, Rost, & Sievers, 1998). In Haussler's model, the construct of "interest in physics" is broken down into three aspects: interest in a particular subject matter of physics (e.g., mechanics); interest in a particular context in which the topic is presented (e.g., physics as a vehicle for understanding technical objects in everyday life); and interest in the particular activity format through which one is engaged with the topic (e.g., learning by doing). The authors reported that, among the 12- to 16-year-old German student participants, these three aspects explained 60% of the variance in student interest, a fifth of which was attributable to the content dimension and the activity dimension, respectively, with the remaining three fifths being contributed by the context dimension (Haussler, 1987). This result suggested that the three dimensions hypothesized in the model were indeed valid and powerful "players" in shaping student physics interest.

It should be pointed out that unlike Haussler's model, which looked at interest in physics as a discipline, the learning environment elements examined in our study are more "fine-grained." In particular, rather than treating student interest in science as a general construct, we chose to focus on student interest in various *instructional episodes*. The topics, activities and learning goals we included were also more detailed, thus enabling us to be specific about what constitutes an *instructional episode* (IE). An *instructional episode* refers to a segment of instruction devoted to a specific content topic or skill, independent of the physical and social aspects of the learning situation. Thus, an IE is an integral and independent potential learning event (e.g., how to draw Venn diagrams) resulting from and constrained by the content and structure of the instructional materials, as well as by the intentions of a teacher.

With IEs chosen as the unit of analysis, our working definition of interest is *a positive affective reaction towards, and a willingness to engage in an instructional episode*. The assumption here is that if students frequently find IEs in their science class interesting, then it is more likely that they will develop enduring interests in science, and that they will learn the material better. Operationally, interest is assumed to exist if students agree with a statement expressing a positive affective reaction towards, or a willingness to engage in a particular instructional episode. In other words, we chose the most commonly used assessment method — self-report (Renninger & Hidi, 2011) — to capture students' interest state, instead of other measures such as online degree of concentration measures (e.g., Ainley et al., 2002) and participatory behavior measures (e.g., Azevedo, 2006). Self-reports are used in this study because of its attested validity in measuring interest (Frenzel, Dicke, Pekrun, & Goetz, 2009), its ease of implementation in classrooms, and (as discussed earlier) the inconclusive nature of using behavioral engagement as an indicator of interest.

With IE as the unit of analysis, the research question we sought to answer was: How do elements of science instructional episodes (content topic, activity type, and learning goal) and their interactions (if any) affect student interest in those episodes.

Methods

Participants

Five hundred and thirty three middle school students from a suburban school district near a major US Midwest city participated in the study, including 187 students from the sixth grade, and 346 from the seventh grade. They were demographically diverse, including 278 girls and 248 boys, and 200 minority students (African, Hispanic and Native American) and 273 majority (European and Asian American) students. Seven students chose not to report their gender, and 60 did not report ethnicity.

Questionnaire

A questionnaire was administered to the participants at the beginning of the school year. The Questionnaire (Supporting Information Appendix 1) included 100 items describing hypothetical IEs that mirrored those in actual science classroom. In order to capture students' perceptions of the interestingness of a wide variety of IEs, each questionnaire item represented a unique combination of IE elements, that is, a unique combination of content topic, activity type, and learning goal.

Several different topics, activities, and learning goals were included in the design.

For the IE element *topic*, four biology topics — Cells, Ecosystems, Diversity of living things, and Human body systems — were included. It was intended that all topics should come from the same content domain in order to avoid the confounding issue that student interest in a particular topic could be masked by his or her lack of interest in the domain to which the topic belonged (Swarat, 2008). The domain biology was thus chosen because it tends to receive sufficient interest from middle school age children, girls and boys alike

(Baram-Tsabari & Yarden, 2009). The specific topics were chosen because of their significance in the middle school science standards (Illinois State Board of Education [ISBE], 2005) and in the curriculum of the participating school district.

For the IE element *activity*, five activity types were included — Brainstorm/Discuss, Create products (e.g., poster), Receive information passively (e.g., listen to a lecture), Design/Conduct investigation *without* scientific instruments or technology, and Design/Conduct investigation *with* scientific instruments or technology. These activity types were selected on the basis of a review of several science curricula, including both traditional (e.g., McDougal Littell Science series, 2005) and innovative (e.g., the Investigating and Questioning our World through Science and Technology or IQWST curriculum) ones. The choice of activities was also motivated by a desire to emphasize the main features that distinguish the variety of activities that occur in science classrooms (e.g., the use of technology, passive vs. active learning).

For the IE element *learning goal*, seven goals were included in the original design — Natural curiosity (i.e., to satisfy curiosity naturally elicited by an observation or experience), Scientific curiosity (i.e., to satisfy curiosity about the scientific properties of or mechanisms behind an object or phenomenon), Personal relevance (i.e., to appreciate the relevance of a scientific or natural phenomenon to the learner's own life), Societal impact (i.e., to appreciate the impact of a scientific or natural phenomenon on the society or environment), Science history (i.e., to satisfy curiosity about the history relevant to an object or phenomenon), Occupation requirement (i.e., to gain science-related knowledge or skills as the basis for a future occupation), and Course requirement (i.e., to meet course or test requirements). The choice of these goals was partly derived from theoretical models such as the Expectancy-Value Model for academic motivation (Eccles & Wigfield, 1992; Wigfield & Eccles, 2000) and the Interest-Driven Learning framework (Edelson & Joseph, 2003), both of which are concerned with sources of student interest and motivation in classrooms. The suggested sources were checked against the learning goals embedded in the variety of science curricula used in the curriculum review process mentioned above, and additional goals were added to the list to reflect the range of learning goals commonly observed in science classrooms.

As mentioned earlier, embedded in each of the 100 questionnaire items was one particular topic, one activity type, and one learning goal. No two items represented the same combination. For example, the item "Look at real data on polar bears to see if global warming is hurting the ecosystem at the North Pole" represented the topic "Ecosystems," the activity type "Design/Conduct investigation without scientific instruments or interactive technology," and the goal "Societal impact." Due to practical concerns (e.g., length of the questionnaire), not all possible topic–activity–goal combinations were included. The excluded combinations were those that were judged to be unlikely or rare in science classrooms. The final 100 items were split equally between the four topics, with 25 hypothetical IEs constructed for each topic. The items for each topic shared the same structure, and were arranged in the same order (e.g., item 1 under the topic "Cells" represented the same activity type and learning goal as item 1 under the topic "Ecosystems"). Items under the same topic were presented together, prefaced by a brief description of the topic to ensure that students understood its content focus. For each of the 100 items, students indicated their degree of agreement to two statements ("I think this task is interesting"; "I would be willing to do this task") using a 6-point scale (1 = completely disagree, 6 = completely agree). An example was provided and explained at the beginning of the questionnaire administration to ensure that the students understood the rating task.

It is our intention to design these 100 hypothetical IEs to resemble what actually takes place in students' science classes as much as possible. Therefore, in addition to grounding the

IE elements (topics, activities, and goals) in existing curricula, we asked the participating teachers to review the questionnaire to confirm that (1) the included IEs were similar to the actual IEs in students' science classes; (2) the phrasing of the items was appropriate for the students; and (3) the rating task was appropriate for the middle school participants to capture their interest in the IEs. It should be pointed out that, even though the teachers viewed the questionnaire as a reasonable task for their students, we recognize the possibility that students could become less serious and focused as they rated the 100 IEs, and thus excluded responses that may indicate such behaviors from our analysis. Specifically, we excluded responses from students who did not complete 50% or more items of the questionnaire, students who completed the questionnaire(s) in an unreasonably short period of time, students gave the same response to all or nearly all items, students whose responses appeared to resemble a deliberate graphic pattern, and students whose manner of questionnaire completion was judged as careless by their teachers. The number of participants ($n = 533$) reported above represents the number of valid responses after this quality control process.

Follow-Up Interview

A small group of participants ($n = 10$) were also interviewed to further understand the effects of IE elements on their interest in the IEs included in the questionnaire. The interview took place about two weeks after the administration of the questionnaire. All ten students, six girls and four boys, were self-selected, and all but one were European American. At the beginning of the interview, students were asked whether they understood the questionnaire, including the description of the content topics and the rating task. The main interview task, however, was to explain students' rating judgments for the IEs rated as most interesting and least interesting for each topic. Because their rating responses were different, the IEs used for discussion varied from student to student, but the IEs were chosen to maximize the variety of content–activity–goal combinations in the limited time available for interview (20 minutes). All interviews were tape recorded, and transcribed verbatim.

Results

Recall that for each questionnaire item, students stated their level of interest by rating two statements. Because the correlation of ratings on these two statements was very high ($r = 0.79$), the average of the two was used as a surrogate variable to represent student interest rating for every item.

Factor Analysis

As already indicated, the 100 items in the questionnaire incorporated many combinations of the four biology topics, five activity types, and seven learning goals. Many of the items were moderately correlated ($0.3 < r < 0.7$). While this is not surprising given that all the items came from the same science domain (biology), it emphasized the necessity to examine the correlational structure of the items, that is, the need to verify how items cluster to form composite scales, and whether these composite scales reflect the topics, activity types and learning goals as intended in the original design.

To this end, the questionnaire item ratings were analyzed in two ways. First, ratings of items within the same topic were averaged to calculate *TopicAvg* — an average interest rating for each topic. That is, each student would have four TopicAvg ratings, each corresponding to one of the topics under investigation. The element *topic* was examined separately because we hypothesized that the items would cluster based on the topics they belong to. This hypothesis was based on the fact that all items under the same topic were listed together in the questionnaire under explicit headings, which presumably would highlight the between-topic differences. Contrary to the hypothesis, however, a comparison of the TopicAvg ratings for four topics (Figure 1) shows that even though the Human body items received slightly higher ratings than the other three, the differences between the topics were very small. Consistently, a parallel analysis (Montanelli & Humphreys, 1976) scree plot also suggested that only one factor should be extracted, which could be interpreted to mean that the item ratings did not distinguish the four content topics from each other. In other words, content topics did not affect student interest in the hypothetical IEs that they rated.

Second, given that the effect of different topics was rather trivial, ratings of items with the same goal–activity structure (i.e., items of the same item number under each topic) were averaged across topics to calculate *ItemAvg* — the average rating for items reflecting the same goal–activity combination (e.g., Personal relevance-Brainstorm/Discuss). That is, each student would have 25 ItemAvg ratings, each corresponding to one of the goal–activity combinations embedded in the questionnaire. The reason for examining the goal–activity combination instead of goal or activity separately is that these elements were represented in the items in an integrated manner (i.e., they were not explicitly described or separated in the items). As such, it is difficult to predict theoretically whether the item clustering would reflect the learning goals or the activity types or either. The observed variation between the ItemAvg ratings for all such combinations (Figure 2) in fact suggests that perhaps either or both of the element *activity* and *learning goal* make a difference in students' interest in the hypothetical IEs.

A minimum residual factor analysis with oblique rotation (oblimin) and bootstrap resampling (number of iteration = 1000) to estimate confidence intervals was thus done using the psych package (Revelle, 2011) under the R statistical language (R Development Core Team, 2007). Three factors were extracted (Tables 1 and 2), and the factor interpretation is summarized in Table 3. As these tables show, items loaded primarily based on the activity type they refer to — "Brainstorm/Discuss" and "Receive information passively" items loaded on the first factor (F1), "Investigation with technology" loaded on the second factor (F2), and "Investigation without technology" and "create product(s)" loaded on the last factor (F3). Learning goals, on the other hand, did not seem to make any difference. We therefore interpreted the item cluster that originally referred to activity types "Brainstorm/Discuss" and "Receive information passively" as representing IEs of a *Purely cognitive* nature, the item cluster that originally referred to activity type "Investigation without technology" and "Create product(s)" as reflecting *Hands-on* IEs, and the item cluster that originally referred to the activity type "Investigation with technology" as reflecting *Technology-based* IEs. In other words, the IE questionnaire data suggested that the original five activity types embedded in the design can be reduced to three types. Items within each of these new types showed high internal consistency reliability (see Table 3).

It should be pointed out that this factor solution may not be the most "clean" solution, as suggested by the factor loading confidence intervals in Table 1. The RMSEA index of the bootstrap resampling results is 0.095, suggesting an adequate, though not excellent, fit. However, we would like to argue that this solution is the most reasonable one in terms of interpretability, and the cross-loadings are likely due to the fact that all items were aimed to measure one general construct — students' interest. To test this hypothesis, we calculated the omega estimate of test saturation (McDonald, 1999) for ItemAvg ratings. The omega-hierarchical is quite large (0.84), suggesting that the variance could indeed be explained by one general factor (g) (Figure 3). Given that all items asked students to rate the interestingness of an IE, we believe that this general factor is students' interest in biology or science in general. In

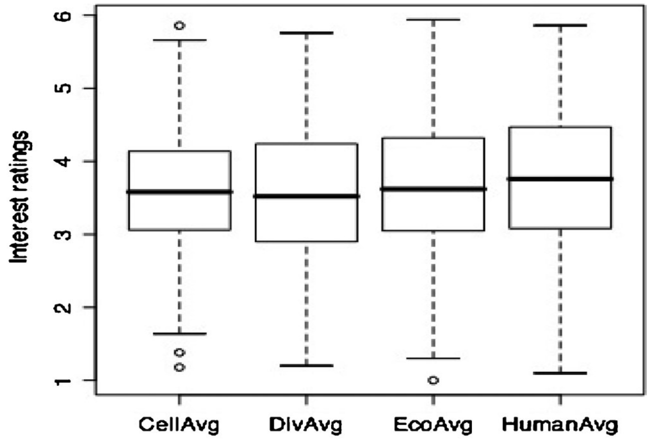

Figure 1. Box plots of TopicAvg* (box showing median, 25th and 75th percentile). *TopicAvg refers to the average interest ratings of each topic. For example, CellAvg refers to the average interest rating of all items under the topic "Cells."

other words, the items could be viewed as both unidimensional and multidimensional—they are unidimensional in that they all measure students' level of interest in science IEs, yet they are also multidimensional because they represent students' interest in IEs consisted of different topics, activities and learning goals. For the purpose of this paper, however, it is not the general factor or the unidimensionality that we are concerned with, but how students' interest is affected by the different IE elements embedded in each IE. Therefore, our analysis is not focused on the general factor, but the three factors (see Table 1) after the impact of the general factor is removed.

In summary, although the original questionnaire items were designed to reflect four different science topics, five activity types, and seven learning goals, the data suggest that for the participants, the dimensions of interest seem to only reflect three activity types (Purely cognitive, Technology-based, and Hands-on) that are aggregates of the original ones, a slight difference between the topic "Human body" and the other topics, and none of the differences

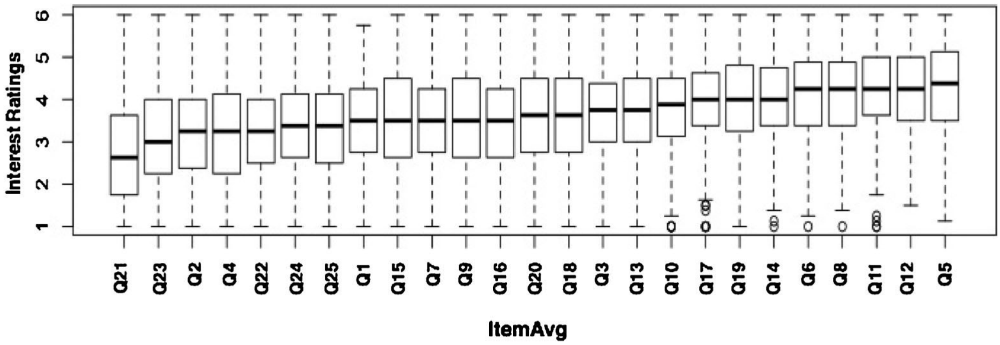

Figure 2. Box plots of ItemAvg (box showing median, 25th and 75th percentile). *ItemAvg refers to the average rating of the same item across topics. For example, ItemAvg of Q3 refers to the average rating of item 3 across all topics. **The specific items can be found in Supporting Information Appendix 1.

Table 1

Factor loadings for questionnaire ItemAvg ratings

ItemAvg Ratings (e.g., avgQ3 Means the Average Ratings of Item 3 Across All Topics)	Activity Category	Learning Goal Category	Loading (95% Confidence Interval)					
			F1		F2		F3	
avgQ21	Receive information passively	Natural curiosity	**0.95**	(0.83, 0.98)	−0.03	(−0.11, 0.05)	−0.10	(−0.20, 0.03)
avgQ2	Receive information passively	Scientific curiosity	**0.84**	(0.60, 0.94)	0.07	(−0.02, 0.16)	−0.05	(−0.18, 0.13)
avgQ23	Receive information passively	Personal relevance	**0.82**	(0.68, 0,90)	−0.04	(−0.11, 0.03)	0.11	(−0.01, 0.24)
avgQ4	Receive information passively	Societal impact	**0.81**	(0.68, 0.89)	0.05	(−0.05, 0.15)	−0.02	(−0.14, 0.13)
avgQ22	Brainstorm/Discuss	Scientific curiosity	**0.64**	(0.51,0.74)	0.08	(−0.05, 0.22)	0.20	(0.06, 0.36)
avgQ1	Brainstorm/Discuss	Natural curiosity	**0.57**	(0.39, 0.70)	0.13	(0.00, 0.24)	0.19	(0.02, 0.39)
avgQ24	Brainstorm/Discuss	Societal impact	**0.54**	(0.39, 0.68)	0.05	(−0.04,0.14)	0.29	(0.15,0.42)
avgQ15	Receive information passively	Course requirement	**0.50**	(0.32, 0.64)	−0.02	(−0.16, 0.11)	0.20	(0.00, 0.42)
avgQ25	Receive information passively	Science history	**0.50**	(0.38,0.61)	0.13	(0.05, 0.23)	0.26	(0.13, 0.38)
avgQ20	Receive information passively	Occupation requirement	**0.49**	(0.33, 0.62)	0.07	(−0.07, 0.20)	0.15	(−0.11, 0.43)
avgQ3	Brainstorm/Discuss	Personal relevance	**0.46**	(0.31,0.59)	0.12	(0.03, 0.22)	0.31	(0.17, 0.46)
avgQ13	Investigation w/instruments or technology	Personal relevance	**0.40**	(0.28, 0,52)	**0.34**	(0.22, 0.47)	0.20	(0.07, 0.33)
avgQ12	Investigation w/instruments or technology	Scientific curiosity	0.09	(0.00,0.17)	**0.82**	(0.66, 0.90)	−0.03	(−0.11,0.12)
avgQ11	Investigation w/instruments or technology	Natural curiosity	0.01	(−0.09,0.12)	**0.65**	(0.52, 0.76)	0.28	(0.14, 0.45)
avgQ14	Investigation w/instruments or technology	Societal impact	0.32	(0.19,0.44)	**0.52**	(0.36, 0.68)	0.04	(−0.12, 0.21)
avgQ10	Investigation w/instruments or technology	Science history	0.36	(0.24, 0.46)	**0.48**	(0.35, 0.61)	0.07	(−0.04, 0.21)
avgQ18	Create product(s)	Personal relevance	0.01	(−0.08, 0.16)	−0.11	(−0.18, 0.01)	**0.90**	(0.73, 0.94)
avgQ9	Create product(s)	Societal impact	0.20	(0.10, 0.34)	−0.17	(−0.27, −0.05)	**0.76**	(0.58, 0.84)
avgQ5	Investigation w/o instruments or technology	Occupation requirement	−0.11	(−0.20, 0.02)	0.24	(0.14, 0.35)	**0.72**	(0.55, 0.82)
avgQ19	Investigation w/o instruments or technology	Societal impact	0.10	(−0.01, 0.24)	0.08	(−0.02, 0.21)	**0.72**	(0.54, 0.82)
avgQ6	Investigation w/o instruments or technology	Natural curiosity	−0.03	(−0.13,0.09)	0.23	(0.13, 0.33)	**0.70**	(0.50, 0.84)
avgQ16	Create product(s)	Natural curiosity	0.16	(0.05, 0.29)	0.01	(−0.08, 0.12)	**0.69**	(0.47, 0.84)
avgQ7	Create product(s)	Scientific curiosity	0.28	(0.17,0.40)	−0.06	(−0.14,0.03)	**0.64**	(0.43, 0.78)
avgQ17	Investigation w/o instruments or technology	Scientific curiosity	0.00	(−0.08, 0.11)	0.32	(0.24, 0.42)	**0.62**	(0.45, 0.74)
avgQ8	Investigation w/o instruments or technology	Personal relevance	0.05	(−0.06, 0.18)	0.25	(0.17, 0.35)	**0.57**	(0.41, 0.69)

Table 2
Between factor correlations

	F1	F2	F3
F1	1	0.48	0.75
F2		1	0.56
F3			1

between the different learning goals. In other words, this finding implies that student interest in the hypothetical IEs was primarily influenced by the activity types, giving little or no consideration to the content topics or learning goals.

Descriptive Statistics

The questionnaire data suggested that the middle school participants in general held a slightly positive view towards school science (Table 4). They seemed to prefer IEs conducted through hands-on activities (mean rating = 3.82) and IEs involving technology (mean rating = 4.00) over purely cognitive IEs (mean rating = 3.31). Differences between demographic sub-groups were quite small, though it is interesting to note that female students expressed slightly higher interest in both Hands-on and Purely cognitive IEs than male students, and minority students expressed slightly higher interest in all types of IEs than majority ones.

Hierarchical Linear Modeling

Hierarchical Linear Modeling (HLM) (also known as multilevel modeling) was used as an additional method to examine the effects of the IE elements. HLM (Raudenbush, Bryk, Cheong, & Congdon, 2004) is appropriate here because item ratings are nested within student (i.e., each student rated the same 100 items), and thus the observed variance between the item ratings is due to both the between-IE variance and the between-person variance. HLM helps to separate out the effect of IE elements from that of individual differences.

Based on the factor analysis results, the independent variables included in the HLM analysis were those IE elements and their corresponding categories that were reflected by the data as distinctive — namely, the content topic “Human body,” and the three new activity types “Hands-on,” “Technology-based,” and “Purely cognitive” (“Purely cognitive” was

Table 3
Factor interpretation for IE questionnaire ItemAvg ratings (showing the types of items loaded on each factor, described by IE element categories)

	F1 (11 Items)	F2 (5 Items)	F3 (9 Items)
Activities	Brainstorm/discussion ($n = 4$); receive information passively ($n = 7$); investigation w/tech ($n = 1$; cross-loading)	Investigation w/tech ($n = 5$; 1 cross-loading)	Investigation w/o tech ($n = 5$); create product ($n = 4$)
Goals	All types; no pattern	All types; no pattern	All types; no pattern
Interpretation	“Purely cognitive” activities	“Technology-based” activities	“Hands-on” activities
Cronbach’s alpha	0.95	0.89	0.94

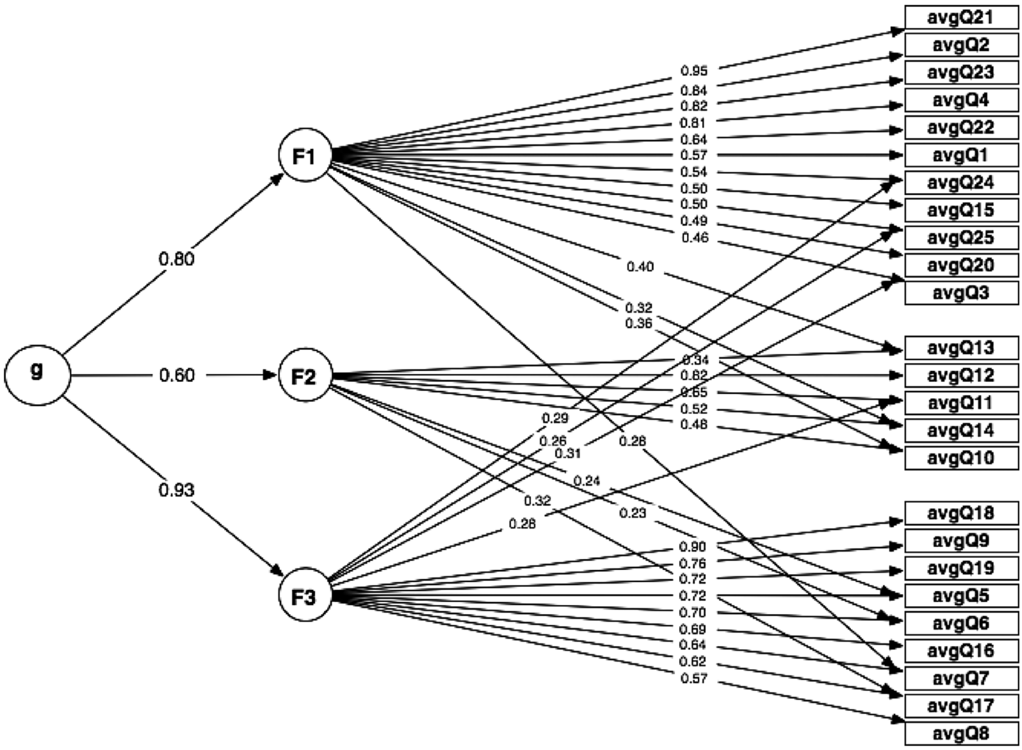

Figure 3. Omega test of factor saturation for ItemAvg. *"g" refers to the general factor; "F1-3" refers to the three factors resulted from the factor analysis; "avgQx" refers to the average rating of the same item × across topics.

used as the comparison group, and thus did not appear in the model). The dependent variable was the students' interest rating. Again, this rating was calculated by taking the average of students' ratings of the two statements for each questionnaire item (i.e., "I think this task is interesting" and "I would be willing to do this task). The use of an average rating is reasonable because of the high correlation between the two ratings ($r = 0.79$).

Table 4
Average interest ratings for hypothetical IEs included in the questionnaire

	All Students, Mean (SD)	By Female Status, Mean (SD)		By Minority Status, Mean (SD)	
		Female	Male	Minority	Majority
All items (1–6 scale)	3.63 (0.85)	3.73 (0.84)	3.53 (0.86)	3.68 (0.82)	3.61 (0.88)
Hands-on items (1–6 scale)	3.82 (0.92)	4.01 (0.88)	3.62 (0.93)	3.85 (0.90)	3.83 (0.94)
Tech items (1–6 scale)	4.00 (0.87)	3.98 (0.90)	4.02 (0.83)	4.05 (0.88)	3.94 (0.86)
Purely cognitive items (1–6 scale)	3.31 (0.93)	3.39 (0.93)	3.24 (0.94)	3.37 (0.90)	3.28 (0.97)

The model is summarized below:

Level 1: The within-individual (or between-item) model

$$(\text{INTEREST})_{ij} = \beta_{0j} + \beta_{1j}(\text{HUMAN})_{ij} + \beta_{2j}(\text{HANDS-ON})_{ij} + \beta_{3j}(\text{TECH})_{ij} + \varepsilon_{ij}$$

Level 2: The between-individual modelThe between-individual model

$$\begin{aligned} \beta_{0j} &= \gamma_{00} + \upsilon_{0j} \\ \beta_{1j} &= \gamma_{10} + \upsilon_{1j} \\ &\dots \\ \beta_{4j} &= \gamma_{40} + \upsilon_{4j} \end{aligned}$$

The HLM results are summarized in Table 5. The coefficients for “Hands-on” IEs and “Technology-based” IEs suggested that these types of IEs on average received significantly higher interest ratings than “Purely cognitive” ones (0.50 and 0.68 points higher respectively on a 6-point scale). The standardized coefficients (calculated as: unstandardized coefficient × SD of predictor/SD of outcome variable) for “Hands-on” and “Tech” were 0.15 and 0.17, respectively. The coefficient for the predictor “Human body” (0.17) is also statistically significant ($p < 0.01$), suggesting that in this analysis IEs under the “Human body” topic on average received higher ratings than IEs under other topics (0.17 point higher on a 6-point scale), although the difference is quite small (the standardized coefficient is only 0.046). It is worth noting that compared to the unconditional model (i.e., without any predictors), the

Table 5
HLM model of association between student interest rating and IE elements

Fixed Effect	Coefficient (All Coefficients Are Significant, $p < 0.01$)	SE
For Intercept1, B0 Intercept2, G00	3.64	0.04
For HANDSON slope, B2 Intercept2, G20	0.50	0.03
For TECH slope, B3 Intercept2, G30	0.68	0.03
For HUMAN slope, B1 Intercept2, G10	0.17	0.03

Random Effect	SD	Variance Component
Intercept, U0	0.85	0.72
HUMAN slope, U1	0.54	0.30
HANDSON slope, U2	0.46	0.21
TECH slope, U3	0.52	0.27
Level-1, R	1.24	1.54

inclusion of these predictors reduced the Level 1 variance from 1.80 to 1.54, an impressive 14.4% decrease.

To summarize, the HLM results were consistent with what was suggested by previous analysis. Specifically, the activity types ‘‘Hands-on’’ and ‘‘Technology-based’’ and the topic ‘‘Human body’’ were positive and statistically significant predictors of the interest outcome. Together they explain almost 15% of the between-item variance, which suggests that these IE elements indeed played an important role in shaping student perception of IE interestingness. Among them, the effects of the two activity type variables were quite prominent, and the effect of the topic ‘‘Human body’’ was quite small. This result once again confirmed that among the IE elements, student interest in the IEs was determined largely by the activity types, and possibly only slightly by the content topic.

It should be noted that models with interaction terms between the ‘‘Human body’’ predictor and the two activity types added were tested, but no significance was observed for these terms, and no significant differences were seen compared to the model without such terms. This result suggested that when rating the IE interestingness, content topic and activity type did not interact to affect students’ judgments.

Follow-Up Interview Findings

The follow-up interview data were analyzed in two ways. First, because the questionnaire data suggested that activity was the most important IE element that affected students’ interest, any interview segments (each segment corresponds to an individual IE) in which students directly discussed the effects of different activities on their interest ratings were extracted. The number of cases in which each activity was discussed is summarized in Table 6.

Consistent with previous analysis, students unequivocally stated that activities involving experiments, lab work or project work were highly interesting, and purely cognitive activities such as brainstorming, reading, writing, and listening to lectures were uninteresting. Students’ views regarding activities involving technology (e.g., computer, Internet, video) were largely positive, although the relatively large number of negative comments ($n = 6$) suggests that perhaps technology was not preferred by all interviewees, and its interestingness might also be affected by the content topic or learning context in which it was used. In addition, although there were more cases in which girls reported the use of technology uninteresting, as well as saying that lectures were interesting (while boys viewed lectures as uninteresting), the number of cases is too small to say anything definitive.

Table 6
Number of cases discussing specific activity types in follow-up interviews

	Considered as Interesting			Considered as Uninteresting		
	Boys	Girls	Total	Boys	Girls	Total
Experiment/Lab/Project	8	7	15	0	0	0
Tech (Computer/Internet/Video)	4	5	9	2	4	6
Brainstorm/Discussion	1	0	1	2	2	4
Lecture	0	2	2	8	4	12
Reading	0	0	0	3	3	6
Writing	1	0	1	3	3	6
Poster	0	1	1	1	0	1

Table 7
Number of cases discussing interactions between IE elements in follow-up interviews

Interaction	IE Questionnaire Follow-Up Interviews
Topic affects students' perception of the interestingness of activity	19
Topic does NOT affect students' perception of the interestingness of activity	4
Activity affects students' perception of the interestingness of topic	5
Activity does NOT affect student's perception of the interestingness of topic	1
Learning goal affects students' judgment of the interestingness of activity	1
Total	30

Second, interview segments in which students discussed interactions between the IE elements (content topic, activity, and learning goal) were extracted. These segments were coded in terms of the IE elements involved (e.g., topic and activity), and the nature of interaction (e.g., with or without effect). The number of cases for each type of interaction is summarized in Table 7.

Thirty cases were identified as involving direct discussions about whether IE elements interacted to affect student interest. Interestingly, while no interactions between content topic and activity were suggested by the questionnaire data, all but one cases here were concerned with the nature of interaction between these two IE elements, with most of them ($n = 24$) suggesting a positive answer. For example, when asked why the IE "Use the Internet to research diseases we can get when cells in our bodies go bad" was rated as interesting, one student, Lily, responded: "Umm, because I think it's an interesting topic, 'cause you really don't hear that much about it, and so we just want to research it to see." She further added, when probed further about the interestingness of the use of Internet: "It depends on the topic." Only one case was concerned with the interactions between learning goal and activity, echoing the finding suggested by the quantitative data that learning goal played no role in students' perception of IE interestingness. No comments regarding the interactions between content topic and learning goal were observed.

Discussion

The Importance of Activity

Perhaps the most important finding of this study is that activity type accounted for most of the explained variance in student interest, whereas content topic and learning goal contributed little or none. In other words, when thinking about how interesting an IE was, students seemed to be mostly concerned with the form of activity, and not so much with the topic and learning goal. Among the different activity forms, students reported higher interest in those that were hands-on in nature and those that involved the use of scientific instruments or technology, and less interest in those that were purely cognitive or less physically engaging.

Part of this finding is not entirely new. Students' preference for activities that actively engage them physically and intellectually is widely recognized (Bergin, 1999; Mitchell, 1993; Palmer, 2009), and has served as one of the underlying themes for major approaches to learning including Constructivism (Piaget, 1970), Constructionism (Papert, 1980, 1991), and Learning by Doing (Dewey, 1906). Such activities are likely to promote student interest and motivation partly because they allow students to make decisions in the course of inquiry, and thus gain a sense of autonomy and competence (Blumenfeld et al., 2006). A synthesis study on the effects of inquiry-based science instruction (Minner, Levy, & Century, 2010) reported several aspects of student outcomes on which inquiry-based teaching practices impact positively, one of which is student motivation, interest, curiosity and enthusiasm. Our study supported this finding, and suggested that this effect is most likely due to the active nature of inquiry-based instruction. The observed preference for hands-on and active learning activities also echos the results of a meta-analysis of different teaching strategies on student achievement (Schroeder, Scott, Tolson, Huang, & Lee, 2007). Based on an examination of 61 such studies between 1980 and 2004, the authors reported "manipulation strategies" (work or practice with physical objects) and "inquiry strategies" (student-centered instruction; students answer scientific research questions by analyzing data) as having significant positive effects on student achievement, with effect sizes of 0.57 and 0.65, respectively.

The use of technology is reported by our participants as an effective way to enhance their interest. This observation is consistent with previous reports on the positive impact of technology-enhanced instruction on students' interest and motivation (e.g., Lepper & Malone, 1987; Mitchell, 1993), as well as on other learning outcomes (e.g., Lee, Linn, Varma, & Liu, 2009, Vogel et al., 2006). We believe that technology may enhance student interest by connecting students with real data and thus promoting a sense of authenticity, and by providing students with easy access to multiple sources of information and thus offering an attractive alternative way of learning (Blumenfeld et al., 1991). However, it should be pointed out that several negative comments regarding the use of technology were also recorded in our study. This suggests that while a technology-enhanced instruction can support learners in many ways, simply including technology into instruction does not, *ipso facto*, make the curriculum more interesting. Further considerations should be given to how to integrate technology with factors such as instructional materials and teaching contexts more effectively.

What is more noteworthy about the finding is that it highlights the need to pay careful attention to the specific form of activity included in curriculum design, an area that seems to have received less emphasis in recent efforts to improve science education. For example, in terms of content topics, science curriculum guidebooks such as the *Benchmarks for Scientific Literacy* (AAAS, 1993) and the *Atlas of Science Literacy* (AAAS, 2001) provided excellent detailed descriptions and conceptual maps of what students should know and be able to do at each grade level. While helpful for determining what materials to include in a curriculum, these guidelines are silent on the question of how such materials should be taught. Similarly, much emphasis has been placed on embedding a meaningful goal (e.g., solving an important problem, pursuing a project of personal relevance) into instruction so as to increase student engagement (e.g., Blumenfeld et al., 2006; Edelson & Joseph, 2003; Pitts, 2006). However, little is said about the form, sequence, and structure of activities through which such goals should be integrated into the curriculum. In other words, whereas of the three IE elements investigated in this study, activity seems to be the most important, it is also the one that has received the least attention in recent years. We do recognize that there is a large body of research focusing on and advocating inquiry-base and technology-based instruction, which as discussed earlier, is complemented by the findings of our study. However, we believe that what is missing is a thorough understanding of the effects of specific forms of activity (within a general instructional approach) on students' cognitive and affective learning outcomes. Palmer (2009) has set a good example of such research, examining how different phases and activities within an inquiry lesson affected students' interest. We believe that similar efforts are needed to explore issues such as the range of activities that are engaging, ways of effectively sequencing activities, appropriate activity forms for different materials and learning goals, and preferred activities for different student populations.

The Collective Effects of IE elements

According to the HLM results, activity type and content topic explained approximately 15% of the observed variance in the interest outcome. This finding echoes the results of Haussler's (1987) study of student interest in physics, in which topic, context, and activity together explained approximately 60% of the observed variance. While both studies concur on the explanatory power of learning environment elements, those examined in Haussler's study seem to have much more effect than those in the present study. This difference might be due to the level of detail of the categories within each element that were used in the investigation. Compared to our study, Haussler broke down his elements using rather broad categories. For example, one of his items for assessing interest was "To build from simple materials some optical devices (e.g., camera, telescope)," which incorporated the topic "optics," the context "physics as a vehicle to understand technical objects in everyday life," and the activity "learning by doing." In contrast, the items included in our questionnaire were more detailed, and often involved reference to specific artifacts and tools that students might engage within the particular IE, all of which could possibly "distract" students from noticing the topic, activity, or learning goal embedded in the item, and result in an interest response that does not correspond *only* to the intended IE element (topic, activity or goal) categories. One might object that the detailed nature of the items used in our study was too distracting, but we believe that our items constituted a more faithful representation of the situations students encounter in real classrooms, where their interpretations of what is to be learned, why it is to be learned, and how it is to be learned are not always clear-cut. Thus, the amount of variance explained by the IE elements investigated in this study, though smaller than that in Haussler's study, should still be considered as indicating the significance of these elements in influencing students' science interest.

Interestingly, neither Haussler's (1987) study nor the quantitative part of this study found any interactions between learning environment elements. Although the qualitative data suggested some interactions between topic and activity, further studies need to be done to confirm whether and to what extent the effect of activity on student interest is moderated by topic.

The Small Effect of Topic

It is intriguing that the questionnaire data suggested a small or even trivial effect of topic on student interest, which seems to be contrary to the fact that people tend to enjoy some topics more than others, and to previous findings that students prefer some science topics over others (Dawson, 2000; Jenkins & Nelson, 2005). We believe that this result may be partly due to the specific topics investigated in our study. The topics embedded in the hypothetical IEs describe four different areas of biology. We chose these topics because they reflect the main content themes of students' existing curriculum, and according to the teachers, the students were well aware of the differences between these topics. We grouped items under each topic together and included a description of each topic to help highlight the between-topic distinctions. However, it is possible that although these topics refer to different areas of biology, the differences between their content foci were still too subtle for middle school students. Perhaps the students simply saw all of the topics as biology, and thus largely ignored the between-topic differences. Therefore, our finding should not be used to completely discount the effect of topic on student interest. In fact, even in our study, several participants reported in the interviews that while activity is a significant factor in their judgments of IE interestingness, their perception of the interestingness of an activity was also affected by the topic associated with it. What is noteworthy about our finding, however, is that the effect of topic — the primary focus of curriculum standards — on student interest is much smaller than that of activity.

Limitations

The questionnaire design used in this study covered a wide range of learning environment elements, and thus yielded a significant amount of data, which from the perspective of statistical power, lent more rigor to the results. Nonetheless, the questionnaire is limited in several respects.

The IEs or items in the questionnaire assumed a structure of "Activity-Content-Goal." That is, they present the form of activity first, followed by the content focus of the activity, and then end with the reason for engaging in the activity. This structure, though helpful in making the items succinct, might have led students to pay more attention to activity type (the first constituent) than to the other two IE elements. Perhaps, when reading the items, students' interest judgments were formed as soon as they saw the description of the particular activity of the IE, while barely attending to the information regarding the content topic or the learning goal. Indeed, this might be what normally happens in classrooms — students easily become excited when they find out they will do an experiment, or get bored when they discover that they will be listening to a lecture, regardless of what the lesson is about and why they are learning it. One way to remedy this issue in future research would be to assess student interest in the individual IE elements separately (i.e., to rate the interestingness of each topic, each learning goal, and each activity type) in addition to rating the interestingness of the hypothetical IEs. Such separate measures could help clarify whether topic and learning goal truly do not exert much effect on student interest, or whether their effects were simply overshadowed due to the emphasis on activity type in the description of the hypothetical IEs.

The hypothetical IEs were structured in such a way that each IE corresponded to one content topic, one activity type, and one learning goal. This design is useful in that it allows for the examination of the effects of IE elements in a more realistic way — students do not normally encounter IE elements in isolation — and it helps reveal any possible interactions between the IE elements. The disadvantage of such design, however, is that it increases the number of items on the questionnaire. With only four topics, five activity types and seven learning goals, the questionnaire (without including all possible combinations) already contained 100 items. Rating 100 items was no doubt quite a laborious task for students at the middle school level. In this study, while all students were instructed to take a short break after completing 50 items, it is likely that some students were more easily "fatigued" than others. Offering different forms of the questionnaire that alter the item order in future studies would help eliminate this problem.

In addition, in order to keep the questionnaire to a reasonable length, only one item per topic–activity–goal combination was included, which makes it difficult to assess the psychometric properties of the items. While we were able to establish content and construct validity through qualitative means (e.g., teacher feedback and student interviews), and to demonstrate adequate internal consistency between items, more rigorous efforts are needed to establish the validity and reliability of the instrument. Specifically, we would like to generate multiple items for the same topic–activity–goal combination using different phrasing, and test them in manageable format (i.e., a shorter questionnaire) with students of equivalent background. Only items shown to best represent each combination and having good psychometric properties would then be included in the final questionnaire.

It should be acknowledged that although the IEs included in the questionnaire were designed to mirror IEs taking place in actual classrooms, the interest ratings captured in this study are nonetheless students' responses to hypothetical situations. An *in situ* study that tracks students' interest to various IEs as they participate in actual science classes would be the reasonable next step. Ideally, if instruction could be arranged in such a way that students experience IEs that vary only on one IE element (i.e., holding the other two IE elements constant), a comparison of their interest responses to these IEs could provide important complementary information on whether and how the particular IE element exerts effect on student science interest.

Lastly, it should be pointed out that, due to practical constraints, students who participated in the follow-up interviews were self-selected, and thus did not necessarily represent the diverse group of students who completed the questionnaire. Thus the interview data should be interpreted as tentative and reflecting perhaps only one type of student opinions. More systematic sampling needs to be done in follow-up studies to gain a more comprehensive picture of student interest.

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