AC 2008-2135: FACTORS CITED BY SECONDARY STUDENTS AS INFLUENCING THEIR INTERESTS IN NANOSCALE SCIENCE AND ENGINEERING

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Factors Cited by Secondary Students’ as Influencing their Interests in Nanoscale Science and Engineering

Abstract

Previous research indicates that interest correlates to student achievement\(^1\) and increased learning.\(^2\) Therefore, if students are more interested in science and engineering concepts, their science achievement may increase. Additionally, hands-on activities\(^3\) and scientific inquiry\(^4\) are explicitly cited as motivational to students. Relevance, context, and applications to real-life have also been shown as factors influencing student interests.\(^5-8\) Although there is a great deal of research that indicates that relevant and meaningful topics increase interest, little research has shown specifically what these topics could be. The focus of this study was to determine the level of interest secondary students expressed in relation to a set of defined nanoscale science and engineering (NSE) concepts and what factors influenced secondary students’ interests in those concepts. A Likert-scale survey was administered to 416 rural, suburban, and urban secondary students to measure their level of interest in four NSE phenomena and 11 driving questions. Forty students were interviewed to investigate why students were (or were not) interested in the survey items. Findings indicated that students were more interested in NSE topics when the activities and concepts indicated relevance to life, were novel, and could be experienced. Both middle- and high-school students indicated interest in the same topics. Gender was found to have little effect on students’ interests, although, males were more interested in mechanics topics, whereas females were more interested in health topics.

Introduction

Statistics from the National Science Board [NSB] (2006) indicate that the number of freshman expressing an interest in majoring in the physical sciences had decreased over the last two decades.\(^9\) On the other hand, the NSB projects indicate that there will be a 26% rise in science and engineering occupations from 2002-2012.\(^9\) Interest and achievement in K-12 science is vitally important to the engineering field as the students that most often pursue engineering as a career are those students with strong abilities and interest in science and mathematics. Nanoscale science and engineering (NSE), with its cutting edge research and innovation has the potential to pique the interest of students whose interest and desire to study science and/or engineering might otherwise wane.

The purpose of this study is to examine secondary (grades 7-12) students’ interests in nanoscale science and engineering. Because of its inherent interdisciplinary nature, nanoscale science and engineering is one way of simultaneously increasing students’ interest in science and engineering as well as infusing more engineering into grade 7-12 classrooms.

Importance of Nanotechnology in STEM Education

The development of nanotechnology comes about through the blending of all science and engineering disciplines on the nanometer scale. Because of this convergence, it is believed that the impact of NSE will be broader than any other technological revolutions. Already, research in the development of nanotechnologies has exploded in nanoelectronics, medicine, healthcare,
pharmaceutical industries, environmental issues, agriculture, energy, biotechnology, and national security. Therefore, an impetus exists to educate the future workforce of scientists and engineers as well as the general public about this emerging field.

Literature indicates a need for the overhaul of the United States science curricula suggesting integrated science courses with the infusion of engineering is an improved practice. This would allow students to explore concepts across science and engineering disciplines. Integrated science and engineering courses unify concepts therefore presenting a more real-world view of science in contrast to traditional science courses, which can potentially increase their interest and motivation to learn. Chemistry, biology, physics, technology, and engineering are all components of nanotechnology making it an interdisciplinary field and therefore providing opportunities to create interconnected and real-world knowledge and coherence in middle- and high-school classrooms.

Research has suggested that students are more motivated to learn and their achievement levels increase when teachers use practices and topics that stimulate student interest. Student interest is often sparked from topics that are relevant to their lives and novel, such as pharmacology topics. Through NSE, many modern applications and products have been produced, such as stain-resistant clothing and paint, which can positively influence the teachings in traditional class settings as they are real-world applications. Due to the integrated, novel nature of NSE and its increasingly greater impact on society and the real-world, this may be one approach to increase students’ interests and motivation in science and engineering, and in turn, increase their achievement levels and will to explore and learn science and engineering.

What Research Says about Student Interest

As defined by Hidi and Renninger, interest is a motivation variable that refers to “a psychological state that, in later phases of development, is also a predisposition to reengage content that applies to in-school and out-of-school learning and to young and old alike” (p.111). Researchers have distinguished two general forms of interest: individual and situational. Individual interest is person-centered and situational interest is situation-centered. Individual interest takes into account an individual’s prior knowledge and current likes and dislikes to determine content and activities that would be appealing to that individual. This form of interest refers to a person’s lasting tendency to partake in certain content and activities over time as well as the person’s “immediate psychological state when this predisposition has been activated” (p. 113). Therefore, individual interest, after its initial development, which is usually slow, is moderately stable over time towards particular fields.

In contrast, situational interest is a psychological state stimulated by particular features of content or activities. The situational approach examines the environment, content, and activities that could generate interest for many people. Situational interest examines the immediate affective response triggered by a stimulus such as content or the environment. This interest may or may not last over an extended period of time.

Importance of Students’ Interests
Motivational factors, specifically an individual’s interest level, plays a crucial role in his or her learning and development as indicated by their engagement in specific content or activities. A person’s interests correlates to his or her attention, goals, and levels of learning. Factors that create both positive individual and situational interests contribute to increased cognitive performance due to more focused attention, persistence, effort, motivation and integration of new information with prior knowledge.

Interest has been found to positively affect deep-level learning as opposed to surface-level learning. Krapp et al. indicated that when interest was triggered, learners used more elaboration and made more connections between concepts as they processed the information that they have been given. The elaboration and connections made between concepts allowed learners to create advanced depictions of the information resulting in better recall of the information. This indicates that if students’ interests are promoted, then their attention and learning can be enhanced.

Factors Associated with Students’ Interests in Science

Students’ interests in science have been found to decline as they progress through school with the largest decline occurring during the seventh grade. This decline in interest has also been correlated to a decline in test performance and student achievement. As students become more interested in science, their achievement levels increase at all academic ability levels.

There are several gender differences in science interest levels. Generally, males believe science to be more exciting, are more interested in science, and also have higher science achievement scores than females. However, this trend is not true for the elementary classroom where girls are more inclined to be interested in science than boys. Although overall interest declines during middle- and high-school, it has been found that boys’ science interest does not change significantly during the middle-school years, while girls’ interest in science declines during these years and their interests instead lean more on the humanities, social studies, and arts. The variance in interest level is potentially due to cognitive levels of learning. Boys were shown to develop quantitative formal operation skills earlier than females, which have been found to positively correlate to interests in STEM subjects. As interests and quantitative formal operation skills are positively correlated, it may be that interest and achievement is more dependent upon these skills rather than gender.

Another factor influencing interest that has been supported by research is relevance. If students find the topic to relate to their lives, to everyday life, to achieving a goal they have, or can identify with the topic, they are more apt to be interested in the topic being discussed. For example, Schwartz-Bloom and Haplin found that when high-school students were taught science concepts using material that were relevant to their own lives, such as pharmacology, significant gains in achievement could be made. This finding supports Brooks and Brooks who found that to foster learning, relevant information should be entrenched within contexts and applications that are meaningful and relevant to the students. The pharmacology topic modules developed by Schwartz-Bloom and Haplin were introduced in both biology and chemistry classrooms, and students in both areas of science made substantial knowledge gains. The researchers believe this was due to the integrative nature of pharmacology and the real-world relevance of the
content of drug and drug abuse. Engineering projects emphasizing a hands-on nature and relevant applications have also been found to have a positive impact on students in both motivation to learn and increasing their abilities in science and math courses.  

As students’ science interests have been found to decline through the middle- and high-school years correlating to a decline in science achievement, an impetus exists to increase students’ interests in science in hopes of raising science achievement scores. Introducing relevant, real-world examples, guided inquiry, and hands-on activities may increase students’ science interests and capabilities leading to more interest in engineering.

**Purpose and Research Questions**

The purpose of this study was to examine secondary science students’ interests in a defined set of nanoscience phenomena and concepts. In addition, we sought to establish what factors influence students’ interests in various nanoscience phenomena and concepts. The following research questions guided the design of the study, data collection, and data analysis:

- What factors influence secondary students’ interests in a set of defined nanoscience concepts?
- How do these factors vary between gender and grade level?

**Methods**

This study is part of a larger research agenda that is focused on student learning and motivation in nanoscience education. The research design for this study consisted of both qualitative and quantitative methods for data collection and analysis. Each participant took part in a standard set of procedures. First, each participant engaged in four short nanoscience activities involving manipulatives (described below). After completing the activities, each participant filled out a short survey (described below). Once students completed the survey, 40 students were selected from the total pool of participants for interviews (described below).

**Participants**

Participants in this study consisted of Midwestern students in middle- and high-schools from predominantly white, middle-class suburban (N=96) and rural (N=164) communities and a diverse, urban community (N=156).

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Forty students from the pool of participants were interviewed to ascertain factors that influenced their level of interest in each phenomenon and driving question. Students were chosen based upon gender and academic ability level in science as determined by the students’ teacher (N=11,
Approximately equal numbers of students from each gender and ability level were interviewed.

**Manipulative Activities**

Four activities with manipulatives were developed to demonstrate nanoscale science and engineering phenomena to the students:

1. The “Waterproof Material” activity provided an example of nanotechnology in their everyday lives.
2. The “Hopping Magnet” activity was used as a model of a scanning probe microscope.
3. The “Changing the Color of Gold” activity illustrated that properties of matter at the nanoscale differ from bulk properties at the macroscale.
4. The “Easy-Stir” activity illustrated how forces affect macroscopic properties.

These activities were used to capture a range of nanoscale phenomena that could potentially influence students’ interests. The activities for this research study were used solely to determine level of interest, rather than students’ level of knowledge about the activities or topics.

**Data Collection**

**Surveys**

A 3-point Likert-type survey to evaluate the nanoscale science and engineering manipulative activities and interest questions was developed. The surveys asked students to rate their level of interest in these topics (not interested, kind of interested, or very interested).

The first section of the survey was developed to measure students’ interest in the four nanoscale science and engineering phenomena described above. The term “phenomena” is used to describe real-world objects, systems, or events in a variety of contexts to make the key ideas plausible.

The second half of the survey contained 11 driving questions designed to measure students’ interest in learning about nanoscale science and engineering and nanotechnology topics as compared to their normal science class. A driving question is a well-designed question used in problem-based science that is elaborated, explored, and answered by both students and teacher.

The words in parentheses will be used later when referring to these questions.

1. How do we know atoms exist (Atoms)?
2. If a penny is made of tiny particles (atoms) why doesn’t it fall apart (Penny)?
3. What do a pencil, diamond ring, car tire, and charcoal have in common (Pencil)?
4. How can a gecko walk upside-down on the ceiling (Gecko)?
5. When will gold no longer be the color gold (Gold)?
6. How did aspirin stop my headache today and my fever last week (Aspirin)?
7. What kinds of machines are small enough to fit inside a living cell (Machines)?
8. What can be done to keep a window clean, making sure water and dirt do not stick (Window)?
9. How can we make DNA act like a robot (Robot)?
10. What do Styrofoam, fog, milk, jell-o, latex paint, and steel have in common (Common)?
11. Why does a CD have so many colors on the back? Do those colors have anything to do with the music stored on it (CD)?
Interviews

A semi-structured interview protocol was developed to investigate why students were (or were not) interested in the manipulative activities and driving questions. The interviews explored students’ interest level for each activity and driving question, as well as if they had any previous knowledge about the topic. Students were also asked how they would change the questions to make them more interesting. The interviews lasted between 20-25 minutes.

Data Analysis

Surveys were coded for interest level of each phenomena and driving question. The mean score of each phenomenon and driving question was calculated with 1 corresponding to not interested, 2 to kind-of interested, and 3 to very interested. Analysis using the t-test and ANOVA were done to test for significance between the student populations on the basis of gender and grade. 32

In order to evaluate why students expressed a given level of interest, the interviews were analyzed using a constant comparative method. 33 This process entailed reading and re-reading the interview transcripts, noting common themes that pertained to students’ interest in the activities and the driving questions about nanoscale science and engineering phenomena from the survey. Once the categories were created, the transcripts were re-read for disconfirming evidence to further refine the categories. Transcripts were then coded using the following categories: (a) relevance to life, (b) novelty, (c) hands-on, (d) no relevance to life, (e) high prior knowledge, and (f) no involvement.

Findings

General Trends

Analysis of the entire population of students’ responses to the phenomena and driving questions indicated that the activities students were most interested in learning about were the Waterproof Pants and Easy-Stir, while students were least interested in learning about the Hopping Magnet. The driving question that the students were most interested in learning about was the CD question, and they were least interested in learning about the Atoms question.
Students were also asked to select their most and least favorite driving questions. Figure 2 indicates the percentage of students responding to each driving question as their favorite and least favorite question. Students most favorite question was the CD (25.5%) question followed by the Gecko (23.5%) and Machines (14.6%) questions, while the least favorite questions were the Atoms (30.4%) and Window (15.6%) questions.

In examining the qualitative data of these questions and activities, students stated they were most interested because the questions and activities (a) had relevance to their lives, (b) were novel, or (c) were hands-on in nature. Students stated that they were least interested in these questions and activities because they (d) did not find relevance to life, (e) already knew the answer, and (f)
were not very involved. Figure 3 below indicates the percentage of students whose comments are classified in each category.

![Figure 3. Percentage of students whose comments were classified in each category.](image)

### Relevance to Lives

Students were interested in driving questions in which they saw relevance to either everyday life or personal interests. Related to this theme, students stated explicitly that the question or activity related to everyday life, society in general, or their personal interest:

> The ones that I was interested in most, the ones that I was very interested in I think, are the ones that would actually affect my life and affect the lives of others. Things that like I can apply to everyday life are worth talking about. While the other things are things that I already know or, umm, just mostly things that I already know or just seem like kind of small to me; they don’t matter so much. –RHS, low male

> [Very interested in the Aspirin] because it’s something that actually can relate to and how like we have those problems and then like it goes away and we don’t know why. –SHS, high female

The example statements elucidate that students are more interested in the questions and activities when they can see a direct relation to everyday life or personal interest. These relations were seen most often in the Aspirin question, but were also seen in the CD question as well as the Waterproof and Easy-Stir activities. The statement by [RHS, low male] indicates the importance of relating topics and concepts to everyday life in that he was interested in the topics and concepts in which a connection to everyday life was made, whereas he was not interested in topics in which relevance to everyday life was not seen.

Students were also interested in the Window question and Hopping Magnet activity due to their personal interest in these topics, even though the question and activity were among those of least interest by the majority of students:
Very interested in Window because I thought that was interesting ‘cause I’d like to have that for my car, you know. You have dirt sticking to it and then the water runs on and you can’t see though it, whereas with that technology, you’d never have to wash it and that’d be nice. So that’s why I liked that one. –RHS, mid-high male

Very interested in Hopping Magnet because I really like magnets and stuff like that and I thought that was really neat that just like the same magnet that’s right there in front of you, you can take off a piece of it and move it across and it would be different and it would skip and everything. I just thought that was really, really cool and interesting and fun. –SHS, high male

Even though a question may be uninteresting to many students, those students like [RHS mid-high male] or [SHS, high male] may have an interest in learning more about the topic because they see a direct application to their everyday life.

Novelty

Students were interested in questions that they felt were novel and addressed phenomena that they had not learned and/ or heard about prior to the study. This theme was present in students’ references to newness or amazement of the question or activity when they did not know that something particular could happen or they did not believe that a phenomenon could happen. For example, two students stated:

Very interested in Waterproof] ‘cause that’s—I’ve actually never seen or heard about stuff that could do that and I just thought it was kind of cool. –RMS, low female

Very interested in Machines because] the machines that are small enough to fit inside a living cells that’s just something I don’t know you’d see on TV, it’s more just like SciFi on TV or can we really do that. –SHS, mid-low male

The students were interested in the Waterproof activity and Machines question as these were new concepts to them. They stated that they did not know such phenomena were possible and did not know much about the topic, which therefore made the topic more interesting to them.

In contrast to the above statement regarding the Machines question, there was one student who was not interested in the Machines question, as the phenomenon was too novel for her to imagine being possible:

Not interested in Machines because] I didn’t think it was fascinating, because if you get a machine in there, then you’re gonna have to get as small as a living cell to get in there to work it, to work the machine. –SHS, low female

For this student, creating machines that are as small as cells is beyond the realm of possibility, a fantasy, and therefore she is not interested in learning about it.
There were also some students interested in the Hopping Magnet and Changing Color activities, two activities of low interest, due to the novelty of the activities. For example, two students stated:

[Very interested in the Hopping Magnet because] I never realized that like magnets do that, so. –RHS, mid female

[Very interested in Changing Color] ah because I’d never heard that you could change the color of gold. I just always thought it was yellowish and I thought it was really cool that ah you can. –SMS, low male

As these students had never heard, seen, or known that magnets could hop or that gold does not always have to be the bulk gold color, they were more interested in learning about the activities.

“Hands-on” Nature

Students were interested in nanoscale activities when they felt the activities were “hands-on,” meaning they involved physical manipulatives. For example, students discussed the hands-on nature of the Easy-Stir experiment:

[Very interested in the Easy-Stir because] I thought it was cool because you actually, you actually did something to the other side, so it’s more then them just putting water in it, and keep on doing that, so… -RMS, high male

[Very interested in Changing Color because] it was immediate and that you could see and you changed something. And that was interesting a lot more, than talking about the theoretical things like the atoms of uh, and what they’re composed of, and how much they weigh, etc. And just it seems to me like one of those things for using chemical reactions to produce different colors and produce different reactions. –RHS, low male

Students were interested in the Easy-Stir experiment as they were able to interact with materials and observe different viscosities of the reaction based upon the solvent added to the powdered chemical. The relationship between the different solvents and the resultant viscosities interested several students. Although the Changing Color activity was of low interest to many students, one student expressed an interest in the activity because it was a hands-on activity with an immediate outcome. Students overall were interested in the activities because they were able to manipulate materials and see something happen in response. Many of the students that responded that they were interested in the hands-on activities were from classrooms that did not incorporate very many activities or experiments in science lessons.

No relevance to ‘my’ life

Students also gave reasons for being not interested in the questions and activities as they did not see relevance to their particular lives. The questions did not attract their personal interests and therefore the students were not interested in the questions or activities:
[Least interested in the Window because] umm...I don’t know, I just felt that was kind of, I mean it would be neat if we had windows where you don’t have to dust them and clean them for fingerprints, but at the same time, I could just get water and wash it off myself, so I wouldn’t really need to know that, or feel the need to explore that, I guess. –SHS, low-mid male

[Not interested in Hopping Magnet because] I don’t really like the magnetic things, like I’m not really into magnets and experiments with them. –SMS, mid female

These statements indicated that students thought that it could be “neat” to see, but it is not something they believe they need to know or learn about. The student not interested in the Hopping Magnet activity elucidated how if an activity does not align with a student’s particular interest, then the student will not be interested. This is also shown in two comments made by students who were not interested in the Gecko and Machines questions.

[Not interested in Gecko because] I don’t really like to learn about animals all that much. I mean they’re interesting, but I like technology a lot more. –SHS, high male

[Least interested in Machines because] I mean it’s interesting, but not as interesting as what I personally like and stuff like that. –RMS, low female

These two students both indicated that although the topic may be interesting and in fact may be interesting to others, the topic is not of particular interest to them due to their personal interests being in other fields/areas.

Already knew the answer

Students were not interested in questions or activities in which they believed they already knew an answer to or had been taught the answer to the question previously. This category also contained statements by students believing the question or activity was an old type of science, rather than novel. This was extremely evident in reasons for why students did not enjoy the Atoms question.

[Not interested in Atoms because] I think it’s just because since I’ve sat in Chemistry class and we’ve talked about atoms and atoms and atoms, just after talking about them for so long, and then doing labs and discoveries with them, not to fond of them. –SHS, low female

[Not interested in Atoms because] umm, last year we did a whole thing on atoms and I just thought, you know, I already know that atoms exist. I know mostly a lot of stuff about those, so, I just didn’t’ find anything exciting about it. –RMS, high male

As seen in the statements above, students are not interested in the Atoms question because they believe they already know the answer to the question of “How do we know atoms exist?” Although students said they knew the answer to the question, they were not always able to provide an answer to the question. In the survey, there was also another question that mentioned
the word ‘atoms’ (the Penny question), and although this was not a question of high interest, students were more interested in this question compared to the Atoms question. This may be due to students seeing a penny as more relevant to their lives than an atom, which as stated above was found to influence their interest.

While the majority of students were interested in the CD and Aspirin driving questions as well as the Waterproof activities, there were some students who were not interested in these driving questions and activities as they had previous knowledge of the answers.

[Not interested in Aspirin because] uh, has to do with pharmacy and stuff like that and like medicine so, pretty much. Like I know it has to do with Chemistry and everything and I kinda know how it works, so… -RHS, mid male

[Not interested in the Waterproof because] well, I pretty much already know how that works, kinda. –RHS, mid male

Although not a majority of the students, these statements bring to light that although a driving question or activity may be interesting to many students, if some students believe they already know the answer to the question, they will not be interested in learning more about it.

Not very involved

Students were not very interested in activities that they deemed to not be very involved, in that they did not see much happen or they did not have to do much in the process of the activity. Much of this was evident in the Changing Color activity, which was an activity of low interest, while one student also mentioned that he was not interested in the Easy-Stir, an activity of high interest among most students, because he did very little in the course of the activity.

[Not interested in Changing Color because] it went from a red to a like a purple or a little darker and I don’t know it just didn’t seem like much happened. –RHS, mid-high male

[Not interested in Easy-Stir] because all we had to do was stir it. It wasn’t like…exciting. –RMS, low male

Students that cited they were not interested in the Changing Color activity believed that the color change was not exciting or interesting as the color change was not drastic. One student stated that although he was not exactly sure was going on, it was just another color change and he has seen lots of experiments with color changes. This statement indicated that students were not able to distinguish this color change activity as anything different from other experiments that they may have done with color changes and the fact that they were changing the color of gold did not appear to influence their interest. The student who was disinterested in the Easy-Stir activity did not enjoy the activity as just stirring a solution was not very involved and therefore his interest was not sustained during the activity.

Gender Trends
Females were more interested than males in all of the manipulative activities, except for the Hopping Magnet activity. Males and females varied significantly in which driving questions they were either very interested in learning about or not interested in learning about. Some of these variations appear to surround particular stereotypes, such as females were more interested in health fields and males were more interested in mechanics. Figure 4 summarizes the findings of gender differences.

![Figure 4](image-url)

Figure 4. Mean of each activity and driving question separated by gender. A value of 1 indicates not interested, 2, kind-of interested, and 3, very interested. Significant differences between districts are reported by an asterisk (p<0.05), a dagger (p<0.01), and a double dagger (p<0.001).

For the total sample population, gender differences were seen in both the Changing Color (p=0.014) and Easy-Stir (p=0.003) activities, in which females were more interested. Driving questions for which gender differences were significant were the Atoms (p=0.004), Pencil (p=0.038), Aspirin (p=0.049), Machines (p=0.000), Robot (p=0.000), and CD (p=0.023) questions. Of these driving questions, females were more interested in the Pencil, Aspirin, and CD questions, whereas males were more interested in the Atoms, Machines, and Robot questions. Some of these differences may be attributed to classic stereotypes of females being more interested in jewelry (diamonds in Pencil question) and health fields (Aspirin), whereas males are more interested in mechanics (Machines and Robot). Although there was a significant difference in the CD question by gender, both sexes were very interested in this question.

Males and females varied in their most favorite questions, while they had the same least favorite questions. Figure 5 summarizes these results. Males favored the Machines (25.1%), Gecko (21.7%), and CD (20.6%) questions, whereas the females favored CD (29.3%), Gecko (24.9%), and Aspirin (12.2%) questions. Although both groups were interested in the Gecko and CD, males were most interested in Machines, while females were not interested in this topic. Both genders (males and females) selected the Atoms (25.3% and 34.3%) and Window (20.1% and 12.2%) questions as their least favorite questions.
Figure 5. Percentage of males and females that selected each driving question as their most favorite and least favorite question.

Although there were significant quantitative differences by gender, males and females tended to cite similar reasons as to why they were or were not interested in the particular activities and driving questions. Figure 6 below indicates that males and females interest level was affected by relevance or lack of relevance and novelty. Males indicated more often than females that they were not interested in a topic due to already knowing the answer or feeling that the activities were not very involved. Females cited more times than males that hands-on activities affected their interest level in the phenomena and concepts.
Examining specific questions also yields the same trends. For example, the students responded that their lack of interest in the Atoms question was due to their previous knowledge of atoms. Approximately equal numbers of males and females also stated their reasons for interest in the Gecko question was due to novelty and personal relevance, whereas their reason for interest in the CD question was largely relevance to life. In examining the Machines and Aspirin questions which were of large disparity between gender, both males and females that were interested in the Aspirin stated that it was due to personal relevance in the concept such that they had taken aspirin before. In examining the Machines question, males were very interested in machines due to the novel nature of the question as well as personal relevance for some students. The females that were interested in this question stated their interest was due to the novel nature. There were also female students not interested in the Machines question stating that it had no relevance to their lives or in the case of one female, the concept was too novel and she could not believe it was a possible event. Due to her dislike in fantasy, she disliked the question. Turning attention to the activities, specifically to the Hopping Magnet, in which males were more interested, males were more interested due to personal relevance, whereas females were disinterested due to a lack of personal relevance.

**Grade-level Trends**

Middle-school students were more interested than high-school students in most of the activities and all of the driving questions. It would have been predicted that middle-school students would be more interested than high-school students from previous research stating that middle-school students are more interested in science.\textsuperscript{23, 24, 34, 35} One activity in which middle- and high-school students had approximately the same interest level was the Easy-Stir activity. The only activity or driving question that high-school students were more interested in learning was the Hopping Magnet activity, although this was not found to be significantly different.

![Figure 6. Percentage of male and female students' comments classified by category.](image-url)

Examining specific questions also yields the same trends. For example, the students responded that their lack of interest in the Atoms question was due to their previous knowledge of atoms. Approximately equal numbers of males and females also stated their reasons for interest in the Gecko question was due to novelty and personal relevance, whereas their reason for interest in the CD question was largely relevance to life. In examining the Machines and Aspirin questions which were of large disparity between gender, both males and females that were interested in the Aspirin stated that it was due to personal relevance in the concept such that they had taken aspirin before. In examining the Machines question, males were very interested in machines due to the novel nature of the question as well as personal relevance for some students. The females that were interested in this question stated their interest was due to the novel nature. There were also female students not interested in the Machines question stating that it had no relevance to their lives or in the case of one female, the concept was too novel and she could not believe it was a possible event. Due to her dislike in fantasy, she disliked the question. Turning attention to the activities, specifically to the Hopping Magnet, in which males were more interested, males were more interested due to personal relevance, whereas females were disinterested due to a lack of personal relevance.

**Grade-level Trends**

Middle-school students were more interested than high-school students in most of the activities and all of the driving questions. It would have been predicted that middle-school students would be more interested than high-school students from previous research stating that middle-school students are more interested in science.\textsuperscript{23, 24, 34, 35} One activity in which middle- and high-school students had approximately the same interest level was the Easy-Stir activity. The only activity or driving question that high-school students were more interested in learning was the Hopping Magnet activity, although this was not found to be significantly different.
Significant differences were observed between middle- and high-school students on the Waterproof (p=0.007) and Changing Color (p=0.000) activities for which the middle-school students were much more interested. Middle-school students were much more interested in the Penny (p=0.000), Pencil (p=0.001), Gecko (p=0.028), Gold (p=0.016), Machines (p=0.000), Common (p=0.039), and CD (p=0.000) questions compared to high-school students. No significant differences were found on the Atoms, Aspirin, Window, and Robot questions. Both groups were equally uninterested in the Atoms and Window questions and were equally interested in the Aspirin and Robot questions.

The driving questions that middle-school students were most interested in learning were the CD (25.2%), Gecko (25.2%), and Machines (14.3%) questions. These students were least interested in learning about the Atoms (36.7%) and the Window (15.6%) questions. The high-school students were most interested in the same three questions as the middle-school students, the CD (25.7%), Gecko (22.6%), and Machines (14.8%) questions. The Atoms (26.8%) and Window (15.6%) questions were also the least interesting question for the high-school students just as they were for the middle-school students. Figure 8 summarizes the results.
The graph below (Figure 9) indicates that high-school students gave more comments than middle-school students. This may have been due to shorter interview times with the middle-school students. The high-school students were also better able to communicate and express their reasons for interest compared to middle-school students who were often unable to express why there were (or were not) interested in the activity or driving question. Although middle-school students often did not provide many comments, they composed the majority of the comments in the no relevance category. Middle- and high-school students also expressed about equally that novelty affected their interest-level in the activities and driving questions. The relevance category and hands-on categories also appear to affect the interests of high-school students more so than middle-school students. High-school students also more often cited that their reasons for little or no interest in the activities and driving questions were due to already knowing the answer or there being little involvement in the activity and driving question.

Figure 8. Percentage of middle- and high-school students that selected each driving question as their most favorite and least favorite question.
Examining each question, middle- and high-school students tended to respond in the same manner as to why they were or were not interested. For example, both grade levels were uninterested in learning about the Atoms question as they had already learned about the topic, whereas they were interested in learning about the Gecko question because of personal relevance and novelty. These groups were also equally interested in learning about the Machines question due to the novel nature of the question.

**Discussion**

Students are more interested in nanoscale science and engineering topics when the activities and concepts are relevant to their lives personally and globally. This relationship to everyday life may explain why most students were very interested in learning about the CD question, as a CD is an object that students can relate to and also enjoy interacting with. Relevance also affected students’ interests in the activities. For example, the Waterproof and Easy-Stir activities were contextualized for the students, whereas the Hopping Magnet and Changing Color activities were not. Students were told in the Waterproof activity that nano-pants are currently being sold in stores and that zinc-oxide powder in the Easy-Stir activity is found in paint and they were encouraged to explore how to create paint from a powder. This contextualization may have been one reason for students increased interests in these activities.

Students tended to be interested in nanoscale science and engineering-related questions and activities that were novel or could be experienced in a hands-on way, rather than questions that were more abstract. As many populations were interested in the Gecko question, it may be because a gecko is a novel animal to them. Some students indicated that they had seen a gecko in commercials and television, but have not interacted with the animal. This conclusion may also partially explain why all populations were least interested in learning about the Atoms question, as atoms are very abstract to students. They cannot interact with atoms, nor see atoms with their eyes.

![Figure 9. Percentage of middle- and high-school students' comments classified by category.](image-url)
Students were more apt to be interested in the activities and questions when their prior knowledge was low. This may explain why the CD and Gecko questions were of great interest, while the Atoms question was of little interest. Students claimed they had little prior knowledge of how CDs work and little prior knowledge or experience with geckos, whereas, they claimed to have learned about atoms repeatedly.

Males were more interested in mechanics questions, whereas females were more interested in health questions; however both sexes were interested in the CD and Gecko questions. Both sexes also stated the reasons of relevance, novelty, and prior knowledge as how their interest was affected either positively or negatively. Similar results were seen with the middle- and high-school groups. Although the middle-school students were more interested in the activities and questions overall, both groups selected the CD, Gecko, and Machines questions as their favorite questions giving reasons of relevance and novelty as reasons for their interest in these questions.

Nanoscale science and engineering concepts lend themselves to motivating students’ interest because of nanotechnology’s current status in society as an advancing field, making it more relevant to students’ lives. Sparking student interest in these topics supports future workforce needs as interest is a component impacting student career choices and success in those fields. The findings of this research have implications beyond NSEE, supporting previous literature that indicates students’ interests are impacted by lessons that are relevant, novel, and use manipulatives.

**Bibliography**


