

# **AC 2007-2278: SECONDARY STUDENTS' BELIEFS ABOUT THEIR INTERESTS IN NANOSCALE SCIENCE AND ENGINEERING**

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# Secondary Students' Beliefs about their Interests in Nanoscale Science and Engineering

## Abstract

Research has shown that increasing students' interests in science has a positive effect on their science achievement;<sup>1,2</sup> however, there is little research as to what topics increase students' interests.<sup>1</sup> Nanoscale science and engineering is one topic currently being investigated as a way to increase students' interests due to its integrated nature and increasing popularity in society. This paper will examine the qualitative data gained from 58 in-depth student interviews of a diverse population. The phenomenographical analysis of interviews identified six characteristics of topics that students report as influencing their interests: relationship of activities or questions to students' personal interests, the relationship of activities or questions to everyday life, prior knowledge, prior experience, the use hands-on or experimentation, and the use of chemicals. Of the six characteristics identified, students' personal interests, the relationship between topics and students' everyday lives, and hands-on activities and experimentation were found to increase interests. The remaining three components – use of chemicals, prior knowledge, and prior experience – showed both positive and negative impacts on students' interests. These results contribute to the efforts of educators working on K-12 curriculum development, creating experiences for students that increase student learning and understanding of nanoscale science and engineering, as well as science and engineering in general.

## Introduction

The National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT)<sup>3</sup> is devoted to developing students' understanding of nanoscale science and engineering concepts. This is important based on 1) the illustrative example provided by the interdisciplinary nature of work in the area, 2) the fundamental understanding of the world provided by knowledge of such concepts, and 3) the impact of nanoscale science and engineering on the general public. One initiative of the NCLT is to do research on the introduction of real-world examples of nano-concepts into secondary (7-12) school science classrooms to support student learning of nanoscale science and engineering.

Previous research has shown that student achievement in science and science-related fields increases when they are taught using relevant, real-world examples. It is not currently known however, which real-world examples might increase students' interests in nanoscale science and engineering.<sup>1</sup> Student motivation, interest, and engagement are important aspects for student learning in science education. Positive student attitudes toward science have been correlated to higher performance on science assessments for the majority of students.<sup>2</sup> Eccles and Wigfield have shown that “interest is more strongly related to indicators of deep-level learning than to surface-level learning” which may explain why students with low interest levels in science perform poorly on exams.<sup>4</sup> As students progress through school, their interest in science appears to decline.<sup>2</sup> A parallel trend has been observed with students' performance on science standardized exams as they progress through school.<sup>5,6</sup> This suggests that the lower performance of older students on these exams is due at least partially to a lack of interest in science.

Several promising strategies have been developed by science educators in an effort to increase students' interests and positive attitudes toward science. Schwartz-Bloom and Halpin investigated the introduction of pharmacology topics into biology and chemistry curriculums and found that this topic was of interest to students in both science areas and thus caused an increase in student learning.<sup>1</sup> Their work builds on previous research that found that when information was submerged within meaningful contexts and applications, learning was promoted.<sup>7</sup> Teaching strategies have also been shown to affect students' interests and learning.<sup>8</sup> One such practice is the use of hands-on activities, shown by Stohr-Hunt, that students "who engaged in hands-on activities every day or once a week scored significantly higher on a standardized test of science achievement than students who engaged in hands-on activities once a month, less than once a month or never."<sup>9</sup> Additional practices that may increase student interests and have been shown to increase student performance include guided inquiry activities and putting an increased emphasis on experiments and practical investigations.<sup>10,11</sup>

Nanoscale science and engineering and nanotechnology are emerging fields that contain concepts and phenomena that are not usually addressed in traditional science curricula, but in which students might be interested. Research efforts in the area of Nanoscale Science and Engineering Education (NSEE) teaching and learning have therefore recently been undertaken in a multi-institutional, collaborative project. This study investigated 7-12<sup>th</sup> grade students' interest in various nanoscale science and engineering concepts and phenomena. In particular, we investigated whether we can identify activities based on nanoscale phenomena that will motivate diverse learners to explore and learn nanoscale science and engineering topics. We also report on students' suggestions for improving interest, and excitement in science class as related to nanoscale science and engineering concepts.

## **Research Design**

### *Theoretical Framework*

Choosing an appropriate theoretical framework is essential in the development of a theory-based qualitative study, as the framework guides the research from the development of research questions to the appropriate data collection methods and analysis.<sup>12,13</sup> To guide this study, phenomenography has been chosen as the theoretical framework. As described by Marton, "phenomenography is the empirical study of the limited number of qualitatively different ways in which various phenomena in, aspects of, the world around us are experienced, conceptualized, understood, perceived, and apprehended."<sup>14</sup> In phenomenography, it is assumed that comprehension of a phenomenon develops from thinking and reflecting on the phenomenon and that any particular phenomenon that society will encounter will be experienced and understood in only a limited number of qualitatively different ways.<sup>12,14</sup> From the limited number of ways a phenomenon can be experienced, categories of description are formed, which can in turn be hierarchically ordered if desired by the study, which is called the outcome space. Phenomenography seeks to comprehend the phenomenon from the subject's viewpoint as opposed to the researcher reflecting upon the phenomenon. Therefore, this study will require the development of a limited number of categories of description to describe factors that students believe affect their interest. As researchers, we seek to understand the phenomenon from the participant's point of view, and therefore we took a neutral stance as much as possible.

Phenomenography is the best fit for this study because students will have already conceptualized their interests of the phenomena and questions prior to the investigation. Students tell the researcher which topics they believe to be interesting and why they perceive these phenomena and questions to be interesting. It is believed that there will be a limited number of ways in which the students will have perceived their reasons for interests in the phenomena and interest questions.

## Methods

### *Participants*

The population 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). From this population, 58 students were selected for interviews based on their gender and academic ability levels in science (N=11, 12, 35 respectively). Students in low, medium, and high achievement levels were selected as described by their science teacher.

### *Instruments*

#### Hands-on Activities

We developed four hands-on activities that demonstrate nanoscale science and engineering phenomena:

1. “The Waterproof Material” experiment demonstrated how nanotechnology directly affects our daily lives, by pouring liquid on both waterproof pants and regular pants.
2. “The Hopping Magnet” was a model of a scanning probe microscope, a critical instrument in the advancement of nanotechnology.<sup>15</sup>
3. “Changing the Color of Gold” illustrated how properties of matter at the nanoscale differ from those at the macroscale.<sup>16</sup>
4. “Easy-Stir” illustrated the power of electric forces on macroscopic properties.<sup>17</sup>

#### Survey

We developed two 3-point Likert-type surveys to evaluate sets of nanoscale science and engineering hands-on activities and interest questions. The surveys asked students to rate their level of interest in these items (not interested, kind of interested, or very interested). The nanoscale science and engineering hands-on activity survey was developed to measure students’ interest in four nanoscale science and engineering phenomena. The interest survey contained 11 questions designed to measure students’ interest in learning about nanoscale science and engineering and nanotechnology topics as compared to their normal science class. The words in parentheses will be used later in 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)?

### Interview Protocol

We developed an interview protocol to investigate why students were (or were not) interested in the items on the hands-on activity interest and general nanoscale science and engineering question surveys. The interviews explored students interest level for each item, and asked students whether they could explain how the activities worked or answer the interest questions. 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 analyzed for the mean of each interest question with 1 correlating to not interested and 3 to very interested. The Mann-Whitney nonparametric test was used to test for significance between the student populations. In order to evaluate why students expressed a given level of interest, the interviews were analyzed qualitatively. Through a phenomenographical analysis, several categories that govern student interest were identified. Categories were created based on common themes seen in the transcripts for questions that pertained to student interests in the activities performed and the questions about nanoscale science and engineering phenomena from the survey, as well as how anything could be changed to increase their interest.

### **Results/Discussion**

#### *Overview of Survey Results*

The mean for each student community from the survey data can be found below in Table 1.

**Table 1. Descriptive results of means for hands-on activity and interest surveys.**

<b><u>Hands-On Activity</u></b>	<b>Means (1=not interested; 3=very interested)</b>					
	<u>Suburban</u>	<u>Suburban</u>	<u>Rural</u>	<u>Rural</u>	<u>Urban</u>	<u>Urban</u>
	<u>High</u> (N=41)	<u>Middle</u> (N=55)	<u>High</u> (N=90)	<u>Middle</u> (N=74)	<u>High</u> (N=63)	<u>Middle</u> (N=13)
1. Waterproof	2.15	2.49	1.97	2.32	2.49	2.15
2. Hopping Magnet	2.20	1.82	1.87	2.16	2.39	2.31
3. Changing Color	1.90	2.15	1.93	2.43	2.17	2.15
4. Easy-Stir	2.20	2.09	2.07	2.35	2.41	2.08
<b><u>Interest Question</u></b>	<u>Suburban</u>	<u>Suburban</u>	<u>Rural</u>	<u>Rural</u>	<u>Urban</u>	<u>Urban</u>
	<u>High</u> (N=41)	<u>Middle</u> (N=55)	<u>High</u> (N=88)	<u>Middle</u> (N=74)	<u>High</u> (N=137)	<u>Middle</u> (N=19)
1. Atoms	1.85	1.76	1.69	1.88	1.76	1.84
2. Penny	1.95	2.18	1.98	2.34	1.87	2.11
3. Pencil	2.24	2.27	2.09	2.50	2.03	2.00
4. Gecko	2.71	2.65	2.53	2.64	2.27	2.16
5. Gold	2.10	2.18	1.92	2.38	2.25	2.32

6. Aspirin	2.56	2.40	2.23	2.47	2.28	2.05
7. Machines	2.41	2.49	2.22	2.58	2.21	2.47
8. Window	2.32	2.02	1.92	1.96	1.90	2.21
9. Robot	2.41	2.35	2.18	2.47	2.32	2.32
10. Common	2.17	2.11	2.06	2.28	1.97	2.05
11. CD	2.68	2.71	2.44	2.82	2.46	2.58

Students of all school populations except the suburban and rural high-schools indicated on the survey that the CD question which discussed the different colors on the back of the CD was of greatest interest. The suburban and rural high-school populations ranked the Gecko as their favorite question and the CD second. The suburban and rural middle-school populations ranked the gecko as second. The Aspirin, Machines, and Robot questions were ranked in the top five questions for the rural and suburban populations. The Pencil question was also ranked as a top five question for the rural middle-school students. The urban high-school students selected CD, Robot, Aspirin, Gecko, and Gold in their top five. This differs from the suburban and rural populations in that these students were more interested in Gold than Machines. The urban middle school population ranked CD, Machines, Gold, Robot, and Window in their top five. This was the only population which selected Window and did not select either Gecko or Aspirin in their top five questions. The Atoms question had the lowest mean in all populations indicating that students were least interested in discovering the answer to this question.

### *Student Interview Results*

The categories that were developed included (a) students' personal interests, (b) relationship of activities to everyday life, (c) prior knowledge, (d) prior experience, (e) hands-on nature/experimentation, and (f) use of chemicals. Table 2 gives an overview of each category, with a description and an example statement or statements depending on the category. Both positive and negative student comments were given if both sets of comments existed in the category. Some student comments were found to fall into more than one category. If this occurred, the comment was coded in both categories.

**Table 2. Descriptions and examples of categories**

Category	Description	Example Statement(s)
Personal interests	Items are related to students' current interests (science and non-science)	<ul style="list-style-type: none"> <li>• [Kind-of interested in the Easy-Stir because] "I'm an artist and I know it had to do with paint and stuff, so...something that I do outside of Chemistry class, kinda like the magnets."</li> <li>• [Not interested in Gecko because] "I like doing like forensic science and stuff like that—like when it comes to like plants and living animals and stuff, I'm not too interested."</li> </ul>
Relation to everyday life	Items relate to general population or everyday life	<ul style="list-style-type: none"> <li>• "I'd like to explore that a little more just because it happens, or it deals with everything around us."</li> </ul>
Prior knowledge	Student already learned or not learned about the topic in science class	<ul style="list-style-type: none"> <li>• "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."</li> <li>• [Regarding the Waterproof material] "I've actually never seen or heard about stuff that could do that and I just thought it was kind of cool."</li> </ul>

Prior experience	Student had personal experience with it, but may not be able to explain it	<ul style="list-style-type: none"> <li>• “All I saw was a color change and there’s a lot of different experiments that, you know, have a different color change”</li> <li>• “I just thought it was kind of cool because I’d never actually tried it or noticed that it would do that.”</li> </ul>
Hands-on/ experimentation	Student recognizes the active process of discovery (or mentions the terms “hands-on” or “experiment(ation)”)	<ul style="list-style-type: none"> <li>• “I like to do like hands-on activities were I can mix up things and see what would happen if I put that with that and that.”</li> </ul>
Use of chemicals	Student used the term chemical in explanation	<ul style="list-style-type: none"> <li>• [No interest in the gold experiment because] “that has a lot to do with like chemicals”</li> <li>• “I’m interested in all the ones that we had to mix different chemicals together because I like to see what happens in the end. And the other ones I was not very interested in because I didn’t get to use different chemical stuff.”</li> </ul>

### Students’ Personal Interests

The category labeled *Personal Interests* was created for statements that related to students’ personal likes and dislikes of topics. This category was separated from *Relation to Everyday Life*, as students in this category related the topic directly to their likes and dislikes, rather than generalizing to life. Statements categorized here were considered unique to the student, rather than something that all students would have in common. This category also contains statements of general curiosity on behalf of the students. As this category contained many student comments, only a selection of comments is included.

#### Not Interested:

- [Not interested in the gecko because] “I’m not really, I don’t really like, not that I don’t like animals, I just, the study of animals just doesn’t really appeal to me all that much. I don’t really like to uh....I don’t really like to learn about animals all that much. I mean they’re interesting, but I like technology a lot more, I like science a lot more then learning about animals and things like that.” –SHS, HM
- [Not interested in Gold because] “Yeah, wasn’t to fond of that because I don’t really know gold. I don’t really have that much gold cause I’m not to fond of the color gold to begin with, so I wouldn’t really care if gold changed colors.” –SHS, LF
- “I mean it wasn’t that interesting to me because I’m more interested in like aeronautical stuff and I guess the more practical side of Chemistry and that wasn’t really one of my interests.” –SHS, L/MM
- [Not interested in Magnet] “because I don’t really like the magnetic things, like I’m not really into magnets and experiments with them.” –SMS, MF
- [Not interested in Gecko because] “I like doing like forensic science and stuff like that—like when it comes to like plants and living animals and stuff, I’m not too interested.” RMS, HM
- [Not interested in Machines because] “I mean it’s interesting, but not as interesting as what I personally like and stuff like that.” –RMS, LF

#### Interested:

- [Kind-of interested in the Easy-Stir because] “I’m an artist and I know it had to do with paint and stuff, so...something that I do outside of Chemistry class, kinda like the magnets.” –SHS, M/LM

- [Very interested in Gecko because] “I’ve always thought it was interesting on how they, it has to do something with their hands that have suction cups that stick on, that I think are really cool, cause I’ve never really played with suction cups and I think they would be really interesting to play with.” –SHS,LF
- [Very interested in the CD] “‘Cuz I’ve always wondered that—like why—why all those colors were on the back and like, I don’t know, I love music—it’s like I have a lot of CD’s. I don’t know it was just weird ‘cuz like—like if you hold it up (inaudible) a certain way like—and it look—it looks like a mirror too.” –RMS, HM
- I just thought that was ummm...very interesting because you know, like, most of the clothing that I wear it can get stained and everything and to know that there’s something where even if I do spill something on myself it will be ok and I just think that’s really cool that they’re starting to make those kind of things so that you know we don’t have to keep buying new clothes all the time. –SHS,HM
- [Interested in Robot because] “I’d like to know how DNA works everything. It’s kinda cool to think of how like DNA is in every cell of your body and it’s just to make it do what you want it to do, so we could just like eventually fix anything in the body. I mean like if you can change DNA since cancer is like just malfunctioning cells, I think we could probably eventually get it to the point where we could fix those cells and make them all better.” –SHS,HM
- [Interested in Robot because] “I just think robots in general are fascinating and it would be cool that if, if they could, if we could get my DNA and give it to a robot, it would act just like me.” – SHS,LF
- [Very interested in aspirin because] “like how does it work with in my body to take it away. Cause it’s something within my body and then you take something, some kind of medicine to make you feel better, how does it know where it’s going to get, to get the pain away?” –SHS,LF
- [In regards to the Aspirin] “I just, I’d like to know why things happen, like medicines and everything. What happens in the body. It’s a chemical reaction, but I’d like to know how one, like little pill can cure two different, many different kinds of ailments and make you feel better and everything. That’s interesting, kind of fun.” –SHS,HM
- [Discussing the Machines] “Cause something that small, like cells are the smallest living organism and to fit something, for humans to make something that small with precision and put it inside of a living organism is just kind of like mind-boggling, cause it’s so small and I would just like to know like what those machines would do.” –SHS,HM
- [Discussing atoms] “Well I would want to know what I’m made up of. So, that would be kind of interesting.” –SMS,MM

This category shows that when the activities or interest questions reflected back onto students’ personal interests, they were positively affected in the area of interest, while if students did not have a personal interest in the activity or question, the students were not interested in learning how the activity worked or the answer to the question. When students had an increased interest, they were more likely to want to learn about the topic. Students’ personal interests varied, for example there were both students that liked animals and did not like animals, which contributed to their interest in the Gecko question. This trend was also seen in examining magnets. Students also described their personal interests in various science and technology disciplines and how these interests described interest in responding to the surveys.



### Relation to Everyday Life

In the category *Relation to Everyday Life* students indicated that the activity or question related to everyday life, but was not specifically unique to their life. Students mentioned the terms “everyday life,” “everything around us,” “relates to me or us,” “interact with,” “see,” and “use often.” This category was differentiated from *Personal Interests* in that it was more general and not specific to the student. This category also included statements given by students as to how to improve science classes.

#### Interested:

- [Interested in Pencil because] “They’re different things that you use in everyday life and you don’t know what’s in common with them whatsoever.” –SHS,LF
- [Very interested in Penny because] “I’d like to explore that a little more just because it happens, or it deals with everything around us.” –SHS,L/MM
- [Interested in 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,HF
- “I don’t really know, like I guess I was just more interested in like for number 18 like there was a pencil and diamond and car tire and charcoal—I guess I was just more interested I guess—that’s things I see more often.” –RMS,HM
- [Very interested in the Pencil] “because they’re different things that you use in everyday life and you don’t know what’s in common with them whatsoever.” –SHS,LF
- [In discussing very interested in Penny] – “I’ve been like, we’ve all been introduced to atoms and so we talk about them, but not really, we didn’t really go too much into it and that’s a good question, why doesn’t the table fall apart or anything? So, I guess I’d like to explore that a little more just because it happens, or it deals with everything around us.” –SHS,L/MM
- [Kind-of interested in atoms because] “I guess that’s, it deals with everyday things still, you know I mean we think they exist, but do we know? We can’t see them, so it’s kinda like exploring I guess, and that appeals to me.” –SHS,L/MM
- [Very interested in aspirin] “Well because like I get headaches a lot, so, I kind of want to know how it works.” –SMS,HM
- “Very interesting ‘cuz I take aspirin a lot.” –SMS,HF
- [Very interested in the CD because] “I look at CDs everyday, I listen to a lot of music and I see the colors but I don’t know if that has to do with anything, with like storing abilities or what they’re for, why they’re there?” –SHS,L/MM

#### Improving Science Class Interest:

- [More interested] if you can relate to ‘em. –SMS,HM
- [More interested] “If there was a way to word them so like I could interact with them in everyday life that I do as a normal, however you define normal, human being. Like how to put into my everyday life then I might be a little bit more interested in it...The more they relate to our everyday lives, the more we’re gonna be willing to pay attention and learn about them cause we can interact with it more than just going to class, sitting in class, and doing the homework, like we can put it to our lives.” –SHS,M/LM
- [More interested if you] “just relate it more to like our age and like things that we know.” –SHS,HF

These students indicated that if the activities or interest questions about nanoscale science and engineering related to everyday life or was something they could interact with daily, then they would be more interested in learning about the topic. Students also indicated that they would be

more interested in science class if what they were doing related more to everyday life. Many times in their science classes students were unable to see any relationship to what they were learning and how it affected their lives. Relating questions and experiments to common experiences of students may help to engage students and motivate them to learn. Although students have various experiences, there are some common everyday life experiences to which science classroom activities could relate. Two questions to which several students responded positively were those asking about aspirin and CDs. Reasons students enjoyed these topics were because they interacted with the items and were able to relate them to their daily lives.

### Prior Knowledge

*Prior Knowledge* is another category that was created. This category is composed of students' comments indicating that they have already learned about the topic or have heard about the topic. Students who discussed doing similar experiments in the classroom were placed in the category *Prior Experience*.

#### Not Interested:

- [Not interested in Atoms because] "I think that I've been asked that question before and I've been told the answer." –SHS, HF
- [Not interested in Waterproof material] "because I have a pair like that... I know about waterproof stuff and try to buy that kind of stuff for myself... it wasn't really interesting cause I've already learned about it." –SHS,LF
- [Least interesting activity] because I know a lot about magnets –SMS,LM
- [Not interested in Atoms] "Cause I think I've done it before." –SHS,HF
- [Not interested in the Waterproof and magnet because have already learned about it]. "The magnet was different polar reactions and I don't really know why the waterproof one works but I know they put like a certain type of chemical like on the pants to repel the water...Cause I remember doing the hopping magnet stuff in 5<sup>th</sup> grade or something and the waterproofing material, I've seen on commercials." –SHS,HF
- "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,LF

#### Interested:

- [Regarding the Penny] "I'm not sure what keeps 'em together and it would be cool to know—find out." –SMS, MF
- [Regarding the Waterproof material] "I've actually never seen or heard about stuff that could do that and I just thought it was kind of cool." –RMS, LF
- "I've been like, we've all been introduced to atoms and so we talk about them, but not really, we didn't really go too much into it and that's a good question, why doesn't the table fall apart or anything? So, I guess I'd like to explore that a little more just because it happens, or it deals with everything around us." –SHS, L/MM
- [Discussing atoms] "I'm not sure what keeps 'em together and it would be cool to know—find out." –SMS,MF
- "I've never really heard of like waterproof thing—like you can really waterproof something. And, I wanted to find out like how, like how it happens." –SMS,LM
- "I've actually never seen or heard about stuff that could do that and I just thought it was kind of cool." –RMS, LF

- [Interested] “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,LM

Students’ interests in a topic decreased when they already had an understanding of the topic and had knowledge as to what was occurring. All of the statements above indicated that if students believed they had already learned the topic, they did not want to revisit the topic. However, even if students believed they had learned about the topic, they were not always able to give an accurate answer to the question. Those students with only a small amount of knowledge about a subject were interested in learning more about the topic. In general, middle school students were more apt to be interested in the activities and interest questions. This can be accounted for as they have less prior knowledge about the questions asked, specifically regarding the questions about atoms (Atoms and Penny).

### Prior Experience

The *Prior Experience* category is differentiated from *Prior Knowledge*, as the student has interacted with the phenomena before. Key words for this section to differentiate from *Prior Knowledge* were actually seeing, doing, and playing.

#### Not Interested:

- [Not interested in gold experiment because] “All I saw was a color change and there’s a lot of different experiments that, you know, have a different color change”-SHS,HM
- [Not interested in the Waterproof and magnet because have already learned about it]. “The magnet was different polar reactions and I don’t really know why the waterproof one works but I know they put like a certain type of chemical like on the pants to repel the water...Cause I remember doing the hopping magnet stuff in 5<sup>th</sup> grade or something and the waterproofing material, I’ve seen on commercials.” –SHS,HF

#### Interested:

- “I remember like when we were younger, I cut up a magnet and did that...I just thought it was kind of interesting doing it.”-SHS, LF
- [Interested in Magnets because] “I just thought it was kind of cool because I’d never actually tried it or noticed that it would do that.” –RMS, LF
- [Very interested in the CD because] “I look at CDs everyday, I listen to a lot of music and I see the colors but I don’t know if that has to do with anything, with like storing abilities or what they’re for, why they’re there?” –SHS,L/MM
- [Interested in Magnets because] “I don’t know magnets are always just kinda cool to like play around with if like you’re bored, so why not learn why they actually do what they do when you’re playing with them.” –SHS,M/LM
- [Very interested in Gecko because] “I’ve always thought it was interesting on how they, it has to do something with their hands that have suction cups that stick on, that I think are really cool, cause I’ve never really played with suction cups and I think they would be really interesting to play with.” –SHS,LF

This category indicated that students who had performed a certain activity many times were not interested, while those that have had a limited amount of experience had an increased interest in the topic. They had interacted with the phenomena or topic of a driving question only a small amount of time and wanted to find out more about it. These students were able to recall doing a similar experiment or playing with the object briefly earlier in life, but never learned what caused the experiment or object to do what it did and they were excited to do it again. Those students

who believed they already had a great deal of experience, and therefore knew a great deal about the phenomena or topic of the interest question, were not interested because they had already done many similar experiments recently in class and believed they understood the principle. The explanations given by the students, however, were not always the correct scientific explanation for how the phenomena or driving question occurred. One experiment commented on by a high-school student was that he did not enjoy changing the color of gold. This experiment changed the color of gold from red to blue, and the student did not feel as if the color change was drastic enough to interest him in finding out why, as it was just “another color change experiment,” similar to titrations. Middle-school students did enjoy this experiment more however, as they have not interacted with as many color change experiments as the high-school students.

### Hands-on/Experimentation

Student responses were placed in the category *Hands-on/Experimentation* if they mentioned that they liked the activity because it was hands-on or an experiment or they were interested in the interest question because they believe that it could be a hands-on experiment when discovering the answer. Several statements were placed in this category when discussing how to increase interest in science class.

#### Interested:

- [Interested in Gold because] “I like to do like hands-on activities were I can mix up things and see what would happen if I put that with that and that.” –SHS,HF

#### Improving Science Class Interest:

- “I like hands-on stuff, so maybe if we did a little more like got deeper into the subjects and you know tested out what the different components or whatever, that might be fun.” –SHS,L/MM
- [More interested] “If there was more like, ah, um like experiment-type questions instead of like what do all these things have in common.” –SMS,MF
- [To increase interest in science class] “Probably to do more projects and see what—if you have in question, but if you could actually do it and see what it would really happen, I think that would be kind of neat to see...like hands-on projects, like that.” –RMS, LF
- [To make science more exciting have] “more like experiments—are always fun to do... I guess experiments and maybe more like group activities.” RMS,HM
- [More interested if you] “Keep it at like stuff that we would like to know about like that we could react with.” –SHS,HF

Students discussed the use of hands-on/experimentation as why they were interested in the activity or interest question, however, this category was mentioned much more in response to how to increase interest in interest questions and science class. Many students indicated that they enjoy hands-on experiments and like testing and exploring to see what will happen. As this category was all positive, it appears that if students are engaged in hands-on activities or experiments, they are more interested in learning about that topic. This may also increase student learning as students will be more apt to pay attention.

### Use of Chemicals

The category *Use of Chemicals* included students’ statements that indicated the term chemicals in response to why they selected their level of interest for the activity or driving question. This category is separate from the *Hands-on/Experimentation* category, as students’ comments that were placed in this category specifically indicated the use of chemicals.

Not interested:

- [No interest in the gold experiment because] “that has a lot to do with like chemicals” – SHS,M/LM

Not interested and Interested:

- “I’m interested in all the ones that we had to mix different chemicals together because I like to see what happens in the end. And the other ones I was not very interested in because I didn’t get to use different chemical stuff.” –SHS,HF

Interested:

- [Very interested in Easy-Stir because] “I think it’s because I just like the fascination of when we put the two chemicals together and it mixed to make a liquid and you can paint with it, I just thought that was really cool. I just like painting.” –SHS,LF

In this category, there was no clear trend seen to determine if use of chemicals increased or decreased interest in the area of study. Some students enjoyed being able to mix chemicals together, while others did not enjoy this task. Although, using chemicals is usually considered to be hands-on which was found to positively affect interest, the use of chemicals in general did not indicate whether students would be more or less interested in the activity or driving question.

## Conclusions

There are several key findings from the results of this study. First, as indicated by the survey, students were most interested in learning about the CD question and least interested in learning about the Atoms question.

Second, students were more interested in the nanoscale science and engineering-related activities and questions if they were able to see a relation to their personal interests or more generally to everyday life. Students discussed how relating topics to their everyday lives would increase their interest in their current science classes. This relationship to everyday life may explain why most students were very interested in learning about the CD, as a CD is an object that students can relate to and also enjoy interacting with.

Third, 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, it may be because the gecko is a novel animal to them. Some students indicated that they have seen them 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 atoms, as atoms are very abstract to students. They cannot interact with atoms, nor see them with their eyes. Students also commented that they would be more interested in science classes if there were more experiments.

Lastly, the use of hands-on activities is not enough to provide interest, as we need to take into account the amount of prior knowledge and prior experience students have with a topic. Students were more apt to be interested when their prior knowledge and experience were low. This trend may also explain why the CD and Gecko questions were of great interest, while the Atoms question was of little interest. Students claim they have little prior knowledge of how CDs work and little prior knowledge or experience with Geckos, whereas, they claim to have

learned about atoms repeatedly. Although, students claim to have learned about atoms, among other topics, they were not always able to give an accurate answer to the question.

Overall, our results suggest that there are certain nanoscale science and engineering topics that interest 7-12 grade students, such as those that are novel and provide room for experimentation. As students' interests have been shown to affect student learning, this increased interest may afford an increase in student learning and understanding in science and engineering fields.

## References

- <sup>1</sup> Schwartz-Bloom, R.D. & Halpin, M.J. (2003). Integrating pharmacology topics in high school biology and chemistry classes improve performance. *Journal of Research in Science Teaching*, 40, 922-938.
- <sup>2</sup> Neathery, M.F. (1997). Elementary and secondary students' perceptions toward science: Correlations with gender, ethnicity, ability, grade, and science achievement. *Electronic Journal of Science Education*, 2 (1).
- <sup>3</sup> National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT). (2006). Available online; <http://www.nclt.us>. Retrieved July 2006.
- <sup>4</sup> Eccles, J.S. & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology*, 53, 109-132.
- <sup>5</sup> Greenfield, T.A. (1997). Gender- and grade-level differences in science interest and participation. *Science Education*, 81, 259-276.
- <sup>6</sup> Haussler, P. & Hoffmann, L. (2002). An intervention study to enhance girls' interest, self-concept, and achievement in physics classes. *Journal of Research in Science Teaching*, 39, 870-888.
- <sup>7</sup> Brooks, J.G. & Brooks, M.G. (1993). In search of understanding: The case of constructivist classrooms. Alexandria, VA: Association for Supervision and Curriculum Development.
- <sup>8</sup> Von Secker, C.E. & Lissitz, R.W. (1999). Estimating the impact of instructional practices on student achievement in science. *Journal of Research in Science Teaching*, 36, 1110-1126.
- <sup>9</sup> Stohr-Hunt, P.M. (1996). An analysis of frequency of hands-on experience and science achievement. *Journal of Research in Science Teaching*, 33, 101-109.
- <sup>10</sup> Glenn, John. (2000). *Before it's too late: A report to the nation from the national commission on mathematics and science teaching for the 21<sup>st</sup> century*. U.S. Department of Education: Washington, D.C. Retrieved March 22, 2002 from: <http://www.ed.gov/inits/Math/glenn/report.pdf>
- <sup>11</sup> Clowes, G.A. (2002). Weak science scores dim hopes for high-tech workforce of the future. *School Reform News*, Retrieved March 20, 2002 from: <http://www.heartland.org/Article.cfm?artId=193>
- <sup>12</sup> Bodner, G.M. (2004). Twenty years of learning how to do research in chemical education. *Journal of Chemical Education*, 81, 618-628.
- <sup>13</sup> Patton, M.Q. (2002). *Qualitative research & evaluation methods* (3<sup>rd</sup> ed.). Thousand Oaks, CA: Sage Publications.

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<sup>14</sup> Marton, F. (1994). Phenomenography. In T. Husen & T. N. Postlethwaite (Eds.), *The International Encyclopedia of Education* (p. 4424-4429). Oxford, U.K.: Pergamon.

<sup>15</sup> Lorenz, J.K., Olson, J.A., Campbell, D.J., Lisensky, G.C., & Ellis, A.B. (1997). A refrigerator magnet analog of scanning-probe microscopy. *Journal of Chemical Education*, 79, (9), 1032A-1032B.

<sup>16</sup> McFarland, A.D., Haynes, C.L., Mirkin, C.A., Van Duyne, R.P., & Godwin, H.A. (2004). Color my nanoworld. *Journal of Chemical Education*, 81 (4), 544A-544B.

<sup>17</sup> Johnson, D.L., (n.d.). Personal communication.