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Impact of Television Presentation Formats on Understanding *DragonflyTV Nano* Content

Report for Twin Cities Public Television
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Small is Different – Presentation format of "onscreen kids doing hands-on activity" to explore reaction of soda to different surface areas of rocks, pebbles and sand

Structure of Matter – Presentation format of "model" using chicken wire to show how structure affects strength

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IMPACT OF TELEVISION PRESENTATION FORMATS
ON UNDERSTANDING *DRAGONFLYTV NANO* CONTENT
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Produced by Twin Cities Public Television, St. Paul, MN, *DragonflyTV* (*DFTV)* is a weekly television series of half-hour live action shows for 8-12 year olds, distributed by PBS Plus. *DFTV* features real children engaged in real inquiry-based investigations in and around science centers across America. Six 2009 episodes of *DFTV* focus on the world of nanoscale science and technology. *DFTV Nano* highlights science centers and university research labs while applying the *DFTV* "Real Kids … Real Science" model to communicate basic concepts and the scientific process in nanoscience. The themes of the six programs include Size & Scale, Structure of Matter, Small is Different, Forces at the Nanoscale, Applications, and Nanotechnology & Society.

Thirty female and thirty male fifth graders equally distributed across five national sites participated in the study. Participants had not previously seen *DFTV* and reported that they were somewhat or very interested in science. Half of the sample viewed the program *Structure of Matter*, and half viewed *Small is Different.* Participants were interviewed individually both before and after seeing their respective program. The pre-post same-sample study implemented by Multimedia Research encompasses two studies (1) an assessment of what children can learn about nanoscience from television and (2) an exploration into how viewers' understanding of nanoscience content varies with different television presentation formats.

The programs were very successful in communicating their main messages of nanoscience

The content in *DFTV Nano* is shaped for the 8-12 year old level of understanding. Both programs used in this study illustrate the meaning of the words nano and nanotechnology and show also how scientists work at the nanoscale. The program *Small is Different* covers the meaning of surface area and demonstrates that when some things are nanosized, they change a lot, influencing their reactivity and their color. The program *Structure of Matter* communicates the message that how something is structured or made on the inside can change the strength of the object or can change the color on the outside of the object. This program also addressed how products use nanoscale material. Pre and post interview questions assessed changes in nanoscience understanding.

Structure of Matter:

- Understanding of the words "nano or nanotechnology." Although three-quarters of fifth graders said they had heard of the words "nano or nanotechnology" before viewing *Structure of Matter*, seeing the show significantly expanded their understanding of the meaning of these words. Half of the sample, both before and after the program, understood "nano" to refer to a very small size. After viewing, significantly more participants understood the terms to refer to something that is too small to see with the naked eye (13% pre; 47% post). In the pre-interview, none of the viewers brought up a property of matter, whereas in the

post-interview a significantly larger proportion (50%) noted something about strength, weight**,** color or structure in their description of the words "nano or nanotechnology."

- Understanding that structure inside can impact strength of object. Significantly more fifth graders in the post-viewing interview could explain how the structure inside something can influence the strength of an object, referencing nanotubes or molecular structures (28% pre; 55% post).

- Understanding that structure inside can impact color of object outside. Significantly more children after viewing the program could explain how something is structured on the inside can change the color of an object outside, referencing light reflection (pre 3%; 46% post).

Small is Different

- Understanding of the words "nano or nanotechnology." Three-quarters of fifth graders said they had heard of the words "nano or nanotechnology" before viewing *Small is Different*. Viewing the program significantly increased understanding that nano means a very small size (pre, 43%; post, 83%), but viewing this program did not significantly increase the percentage of children who understood the nanoscale size as too small to see with the naked eye (pre, 7%; post, 17%). Significantly more children in the post-viewing interview noted something about change in reactivity or color in their description (pre, 0%; post, 30%).

- Understanding that some things change a lot when nanosized. Viewing the program significantly improved the fifth graders' ability to verbalize an understanding that nanosizing something influences its properties like reactivity or color. Prior to seeing the program, none of the children made reference to the properties of matter as a function of size, whereas after viewing, significantly more (47%(referred to the reactivity or color results of nanosizing.

- Understanding surface area. Significantly more viewers could provide an acceptable definition of surface area after seeing this program. (pre, 30%; post, 60%).

Viewers identified two distinct television presentation formats as most effective in helping them learn nanoscience content: "onscreen kids doing hands-on activities" and "the use of models to support content"

With each post-viewing interview question about nanoscience content (summarized above), viewers were asked also what particular parts of the program helped them learn that content. Four presentation formats widely used in the production of the two programs were of interest in this study: (1) onscreen kids doing hands-on activities; (2) onscreen kids meeting with adults who show them something; (3) use of models to support content explanations; and (4) the host, Eric, explaining directly to the viewing audience.

- Viewers most frequently pointed to the presentation format of onscreen kids doing hands-on activities as helping their understanding of the words "nano," "nanotechnology" and "surface

area;" that some things change a lot when nanosized; what happens when surface area increases a lot; that structure inside can impact strength or color of an object; how scientists work at the nanoscale; and what products use nanoscale structures.

- The second most-effective format supporting the learning of nanoscience content was the use of models, which viewers identified as helping them understand the phrase "surface area;" that some things change a lot when nanosized; and that structure inside can impact strength of an object.

- Viewers less frequently referred to the presentation format of onscreen kids meeting with adults who show them something. When scientists showed images of nanoscale structures produced by large microscopes, viewers learned how scientists work at the nanoscale and that nanoscale means smaller than can be seen by the naked eye.

- The format of the host Eric explaining directly to the audience was least noted in helping viewers except in the recall of products using nanoscale structures.

Across the presentation formats, four production characteristics were identified as most effective in helping viewers learn: "clear demonstration of relationships, comparisons, procedures and results," "showing critical information visually," "connection to the content" and "clear age-appropriate explanations"

Viewers explained how different segments within the four presentation formats helped them learn something. This part of the post-interview permitted the identification of production characteristics that support learning, including:

- Clear demonstration of relationships, comparisons, procedures, and results was noted as important to effective learning from all four presentation formats.

- Showing critical information visually was also described as a critical attribute for all four formats.

- Viewers felt connected to the content of three of the four formats (hands-on activities, models, host)

- Viewers emphasized that explanations were age-appropriate and clear in three of the four formats (models, host, adults showing something to onscreen kids).

- The hands-on activity and host segments were described as fun or funny.

- Viewers felt that they could do the activity presented in the hands-on activity format.

- With respect to the segments where the onscreen kids meet with adults who show them something, viewers felt they could learn along with the onscreen kids, that the scientists know more, and that they could really see how small the nanoscale is.

All viewers concluded that nanotechnology will be very or somewhat important in the future

Viewers of the two programs came away thinking that nanotechnology will be important in the future because it can be applied in many different ways; it may make life easier; it uses fewer resources, saves money or has the potential to produce better sources of energy; and that nanotechnology stimulates building or inventing new things.

In conclusion, this study demonstrates that the *DragonflyTV Nano* television programs can significantly expand pre-teens' understanding of nanoscience in terms of scale, properties, methodology and applications. The television presentation formats of showing "onscreen kids doing hands-on activity" and "models" were perceived by viewers as most effective in communicating the nanoscience messages, and the characteristics of *DFTV Nano*'s presentation formats that were identified as most helpful for learning include "clear demonstration of relationships, comparisons procedures and results," "showing critical information visually," "connection to the content," and "clear age-appropriate explanations."

INTRODUCTION

Produced by Twin Cities Public Television, St. Paul, MN, *DragonflyTV* (*DFTV)* is a weekly television series of half-hour live action shows for 8-12 year olds, distributed by PBS Plus. *DFTV* features real children engaged in real inquiry-based investigations in and around science centers across America. Six 2009 episodes of *DFTV* focus on the world of nanoscale science and technology. *DFTV Nano* highlights science centers and university research labs while applying the *DFTV* "Real Kids … Real Science" model to communicate basic concepts and the scientific process in nanoscience.[1] The themes of the six programs include Size & Scale, Structure of Matter, Small is Different, Forces at the Nanoscale, Applications, and Nanotechnology & Society.

Participants in this study viewed one of two *DFTV Nano* programs: *Structure of Matter* or *Small is Different.*[2] Both programs illustrate the meaning of the words nano and nanotechnology and also how scientists work at the nanoscale. The program *Structure of Matter* communicates the message that how something is structured or made on the inside can change the strength of the object or can change the color on the outside of the object. This program also addresses how products use nanoscale material. The program *Small is Different* addresses the meaning of surface area and demonstrates that when some things are nanosized, they change a lot, influencing their reactivity and their color. The content in both programs is shaped for the 8-12 year old level of understanding.

The pre-post same-sample study implemented by Multimedia Research encompasses two studies: (1) an assessment of what children can learn about nanoscience from television and (2) an exploration of how viewers' understanding of nanoscience content varies with different television presentation formats. The four presentation formats of interest in this evaluation include (1) the host explaining directly to the viewing audience; (2) the use of models to support content explanations; (3) onscreen kids doing hands-on activities; and (4) onscreen kids meeting with adults who show them something. Both the programs and presentation formats are explained in more detail in the next section.

[1] For a more complete description, see http://www.dftvpress.org/index.html

[2] Full programs may be viewed at http://pbskids.org/go/video/ . Individual video segments may be viewed at http://pbskids.org/dragonflytv/nano/ as listed in Tables 1 and 2.

METHOD

Sample

Sixty fifth graders participated in the study, equally distributed across five national sites (North Miami, FL; Harvard, MA; Milwaukee, WI; Austin, TX; Sacramento, CA). Half of the sample (15 girls, 15 boys) viewed *Structure of Matter*. Minorities comprised 27% of the girls' sample and 27% of the boys' sample. A different half of the recruited participants (15 girls, 15 boys) viewed the program *Small is Different.* Due to scheduling issues, few minority participants (10%) viewed *Small is Different*. The study did not plan comparisons of the two programs so this imbalance is not a problem for the research design but does influence generalization of results. Children familiar with *DFTV* or with "little" or "no" interest in science were not recruited for the study; thus, no viewers had seen *DFTV* previously, and viewers reported that they were either "very" (53%) or "somewhat" (47%) interested in science. Gender and minority status were not related to strength of interest in science.

DFTV Nano Programs

Two *DFTV Nano* programs were utilized in the study. Tables 1 and 2 present the program segments of *Structure of Matter* and *Small is Different* along with their nanoscience messages and presentation formats that are the focus of this study. The images displayed are thumbnail versions of photos shown to participants in the second half of the post-viewing interview.

Table 1. ***Structure of Matter***

Nanoscience Messages	**Presentation Formats**	**Illustration from program used in interview**
Host Intro		
Meaning of nano and nanotechnology Structure at the nanoscale impacts physical properties at the macroscale	Host explains directly to audience how different combinations of carbon atoms form different structures.	
Real kids hockey sticks inquiry (http://pbskids.org/dragonflytv/show/hockeysticks.html) Nicholas and Jordan love hockey. They know that carbon nanotubes are used in some hockey sticks but aren't sure how the tiny structures change the equipment. They do some background research at the Museum of Science and do an experiment with hockey sticks.		
	Balloon model of shape and structure of a carbon nanotube at Museum of Science, Boston.	

Structure at the nanoscale impacts physical properties at the macroscale	Chicken wire used to model how structure changes strength of material.	
	Kids do hands-on activities, measuring and graphing slap shot speed with carbon nanotube, wood, and composite hockey sticks.	
Host discusses nano applications, size, and introduces challenge question: How do you get into space without a rocket?		
Real kids hockey sticks inquiry continued At a Harvard University lab, Nicholas and Jordan compare tensile strength of the hockey sticks, and Harvard scientists use powerful microscopes to help the kids "see" carbon nanotubes.		
Meaning of nano and nanotechnology Structure at the nanoscale impacts physical properties at the macroscale	Kids do hands-on activities, measuring the weight and strength of the three types of sticks.	
	Kids meet with adult who shows them pictures of carbon nanotubes using transmission electron microscope.	
Host discusses carbon nanotube applications, size, gives hint about challenge question		
Scientist profile: Lesley Hamming, mussel scientist, discusses nanoscale mussel glue http://pbskids.org/dragonflytv/scientists/scientist64.html		
Host discusses nano in nature		
Structure at the nanoscale impacts physical properties at the macroscale	Host explains directly to audience that spider web's nanostructure makes it, by weight, stronger than steel.	
Zoomcab: Host rides animated car, zooming through macroscale images down to nanoscale images of an iridescent moth wing.		

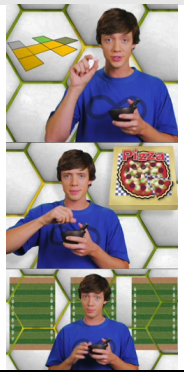
Structure of Matter (continued)

<table>
<tr><th>Nanoscience Messages</th><th>Presentation Formats</th><th>Illustration from program used in interview</th></tr>
<tr><td colspan="3">Real kids butterfly wings inquiry http://pbskids.org/dragonflytv/show/butterflywings.html
Emily and Julie check out the Magic Wings Butterfly House at the Museum of Life and Science in Durham. They wonder why some butterfly wings change color when you tilt them and others don't.</td></tr>
<tr><td>Structure at the nanoscale impacts optical properties (i.e., iridescence) at the macroscale</td><td>Kids do hands-on activities, observing that the color of soap bubbles has something to do with the thickness of the soap film.</td><td>  </td></tr>
<tr><td colspan="3">Real kids butterfly wings inquiry continued
At a Duke University lab, Emily and Julie learn that iridescence in some butterfly wings – like the iridescence of soap bubbles – results from their structure. They test whether colors in butterfly wings are the result of pigment or nanoscale structures.</td></tr>
<tr><td rowspan="2">Meaning of nano

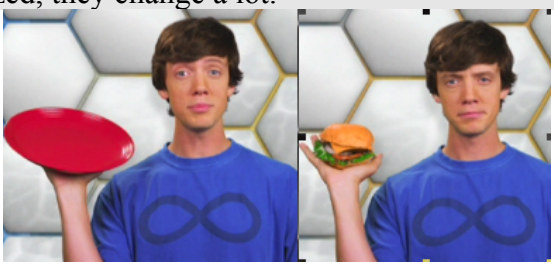
Structure at the nanoscale impacts optical properties at the macroscale</td><td>Kids meet with adult who shows them pictures of Blue Morpho wings using scanning electron microscope.</td><td>  </td></tr>
<tr><td>Kids do hands-on activities, testing the presence of pigment or nano structures in butterfly wings.</td><td>  </td></tr>
<tr><td colspan="3">Host Expansion</td></tr>
<tr><td>Structure at the nanoscale impacts optical properties at the macroscale</td><td>Host explains directly to audience how a future nanofiber shirt will change color with a tiny electrical charge.</td><td>  </td></tr>
<tr><td colspan="3">Hey, Wait a Nanosecond shows interviews with real kids answering the question: Would you want to know if a product was made with nanotechnology?[3]
http://pbskids.org/dragonflytv/nano/wans_702.html</td></tr>
<tr><td colspan="3">Host closes with discussion of the challenge question about the possibility of traveling into space without a rocket with a nanotechnology-based space elevator.</td></tr>
</table>

[3] Societal and ethical aspects of nanotechnology were noted in the program but not addressed in this study.

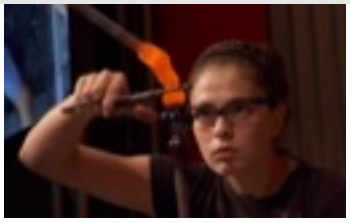
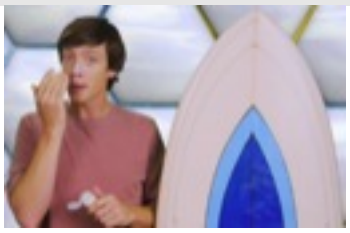
Table 2. ***Small is Different***

Nanoscience Messages	Presentation Formats	Illustration from program used in interview
Host Intro		
Meaning of surface area The same substance can behave very differently when nanosized	Host demonstrates directly to audience how surface area of antacid tablet (whole or crushed) influences dissolving speed.	
Real kids surface area inquiry http://pbskids.org/dragonflytv/show/surfacearea.html After discovering that ordinary flour dust can be explosive, Lara and Anushua coat small and big cookies with sugar and then explore surface area to volume ratio at the Science Museum of Minnesota.		
Meaning of nano Meaning of surface area The same substance can behave very differently when nanosized Surface area affects reactions	Kids meet with adult who shows them how flour dust can explode when surface area is increased, at Mill City Museum in Minneapolis.	
	Kids do hands-on activities, discovering that cookies of different sizes require different amounts of sugar to cover them.	
	Blocks used to model surface area to volume ratio at Science Museum of Minnesota, St. Paul.	
Host demonstrates surface area and introduces challenge question: What can you find in your kitchen that could help propel rockets into outer space, if broken down into nano-sized pieces?		
Meaning of surface area Meaning of nano	Sugar used to model the difference in surface area of a sugar cube, powdered sugar, and nano-sized powder.	

Small is Different (continued)

Nanoscience Messages	**Presentation Formats**	**Illustration from program used in interview**
Real kids surface area inquiry continued Lara and Anushua conduct soda explosion experiments, investigating how surface area affects reactions. At the University of Minnesota, scientists demonstrate solar cells designed with nanotechnology to increase the cells' surface area.		
Meaning of surface area Meaning of nano and nanotechnology Surface area affects reactions	Kids do hands-on activities, measuring the height of geysers produced by adding the same weight of rocks, pebbles and sand to soda.	
	Kids meet with adult who shows them the electrical energy of different solar cells, including one with high surface area nanowires.	
Host discusses how when some things are nanosized, they change a lot.		
The same substance can behave very differently when nanosized	To model how strange stuff happens at the nanoscale, the host imagines a dinner plate changing so much that it becomes a cheeseburger at the nanoscale.	
Scientist profile: Christy Haynes, chemistry professor, discusses safety of nano material and how exposure to nanoparticles can affect communication of cells. http://pbskids.org/dragonflytv/scientists/scientist65.html		
	A Marco Polo game is played by graduate students to model how cells respond after exposure to nanoparticles.	
Host gives hint about challenge question		
Zoomcab: Host rides animated car, zooming through macroscale images down to nanoscale images of an eye.		

Small is Different (continued)

Nanoscience Messages	**Presentation Formats**	**Illustration from program used in interview**
Real kids stained glass inquiry http://pbskids.org/dragonflytv//show/stainedglass.html Alettie and Yvonne visit the Glass Experience exhibit at the Museum of Science and Industry, Chicago, and learn that nanoparticles are responsible for colors in some medieval stained glass. At Northwestern University, they produce nanoparticles to explore the relationship between size and color, making their own glass suncatchers.		
Meaning of nano and nanotechnology The same substance can behave very differently when nanosized Size of particles can affect light reflection/color	Kids meet with adults who show them the making of glass.	
	Kids do hands-on activities, making gold and silver nanoparticles of different sizes that turn solutions different colors.	
Host Expansion		
Meaning of nano and nanotechnology The same substance can behave very differently when nanosized Size of particles can affect light reflection/color	Host explains directly to audience how regular zinc oxide sunscreen reflects light as white and nanosized zinc oxide does not scatter light and goes on clear.	
Hey, Wait a Nanosecond shows interviews with real kids answering the question: Do I think nanotechnology is safe or unsafe ?[4] http://pbskids.org/dragonflytv//nano/wans_703.html		
Host closes with discussion of the challenge question: aluminum becomes very flammable at the nanoscale because the nano aluminum particles are more reactive due to greater surface area.		

[4] Societal and ethical aspects of nanotechnology were noted in the program but not addressed in this study.

Procedure

Pre-viewing procedure. A pre-interview focused on what the fifth graders knew about nanoscience. Participants were reassured that there were no right or wrong answers to the questions. Two opening questions were asked of all participants:

1. Have you ever heard of the words "nano or nanotechnology"?
2. Give me your best guess about what you think the words "nano or nanotechnology" means.

Different content questions were asked prior to viewing the respective program:

Structure of Matter

3. How something is structured or made on the inside can change the strength of the object. Give me your best guess about what you think that statement means – how something is structured or made on the inside can change the strength of the object.
4. How something is structured or made on the inside can change the color on the outside. Give me your best guess about what you think that statement means – how something is structured or made on the inside can change the color on the outside.

Small is Different

3. When some things are nanosized, they change a lot. Give me your best guess about what you think that statement means – when some things are nanosized, they change a lot.
4. Have you ever heard of the phrase "surface area"?
5. Give me your best guess about what the phrase "surface area" means.

Viewing procedure. One week to a few days after the pre-viewing interview, children viewed one of the two half-hour programs in their home and were interviewed immediately after.

Post-viewing procedure. The first half of the post-interview established viewer understanding of the nanoscience content by repeating the pre-viewing questions listed above. Additionally, the interview explored the relationship of learning to presentation formats by asking viewers after each content question to identify and reflect on what parts of the program helped them to learn the content. For example, after asking "*what do you think the words 'nano' or 'nanotechnology' mean*," the interviewer asked "*what particular part in the show helped you learn that?*" An additional question was asked for each program related to the nanoscience content: For *Structure of Matter*, the interviewer asked: "*Some parts of the show explained how nanoscale structures are used in products. What part do you remember that explained this idea – how nanoscale structures are used in products?*" For *Small is Different*, the interviewer asked: "*Some parts of the show explained what can happen when surface area increases a lot. What part do you remember that explained this idea – what happens when surface area increases a lot.*" For both shows, interviewers also asked: "*What part of the show helped you understand something about how scientists work at the nanoscale?*"

The second half of the post-interview focused specifically on the four presentation format categories. For each category, researchers showed viewers the segment photos that appear in Tables 1 and 2 and asked them to choose one segment that helped them learn the best and to reflect on how that segment was effective in helping them learn. Viewers also chose the most effective presentation format from among their four category choices. Finally, viewers were asked how important they thought nanotechnology will be in the future and why. Upon completion of the procedure, each family received an honorarium of $35.

Data Analysis

The interview data are both quantitative and qualitative in nature. Quantitative data are presented with frequency distributions in percentages. Qualitative data are coded by key word or phrase to identify patterns and themes related to the goals of the study. Note that all quotes from viewers in this report are verbatim and reflect the fifth graders' abilities to verbalize answers. Non-parametric statistics[5] are used to test the statistical significance of proportion differences. In this study, a statistical test that gives a p-value, or probability value, lower than .05 is reported as "statistically significant." Tables present rounded percentages, so columns may not add to 100%.

[5] Non-parametric measures (McNemar Test of Paired Proportions, Chi-square) are used when the assumptions of parametric tests may not be met, small samples are used, and when data are in ordinal or nominal scales. In this report, footnotes present the statistical test results.

RESULTS: *STRUCTURE OF MATTER*

Understanding of the Words "Nano or Nanotechnology"

Although three-quarters of fifth graders said they had heard of the words "nano or nanotechnology" before viewing *Structure of Matter*, seeing the show significantly expanded their understanding of the meaning of these words. Half of the children reported both before and after viewing the show that nano means a very small size. Significantly more children in the post-viewing interview added that nano could not be seen with the naked eye and noted some property of matter in their description. Viewers identified two presentation formats as helping their understanding the most: The format of "onscreen kids meeting with an adult who shows them something," in particular microscope images of carbon nanotubes, helped viewers to understand that nano means too small to see with the naked eye. The "hands-on activity" format, particularly the hockey stick inquiry, helped viewers to understand that nanotechnology has to do with properties of matter.

Before viewing *DFTV Nano: Structure of Matter*, three-quarters (73%) of fifth grade participants said they had heard of the words "nano or nanotechnology". Before viewing the program, the children were asked: *"Give me your best guess about what you think the words "nano or nanotechnology" mean?"* After viewing, they were asked: *"Now that you have watched this show, what do you think the words "nano or nanotechnology" mean?*" The goal of these questions was not to elicit a specific scientific definition but to assess how viewing the show might expand viewers' understanding of the terms.

Viewing the program significantly improved the children's ability to verbalize some relevant understanding about the terms, with 37% of the sample indicating no relevant understanding before seeing the program and 100% showing some relevant understanding after viewing[6] (see Table 3).

Table 3. Understanding of the Words "Nano or Nanotechnology" (N = 30)

Category of Response	% Pre	Examples of pre answers	% Post
No relevant understanding	37%	*Well, I've heard it as in iPod nano.* *How something works.* *I think it's a special type of a laptop or a computer.*	0%

[6] McNemar One-Tailed Test of Paired Proportions, as applied here, assesses the equality of before and after proportions for the same sample. $p = 0.0004$.

Half of the sample, both before and after the program, understood "nano" to refer to a very small size. After viewing, significantly more participants understood the terms to refer to something that is too small to see with the naked eye; 13% gave this category of answer prior to viewing and 47% after viewing.[7] (see Table 4).

Table 4. Understanding of Size Related to Words "Nano or Nanotechnology" (N = 30)

Category of Response	% Pre	Examples of pre answers	% Post	Examples of post answers
Understands size as very small	50%	*It has to do with something that is really small.* *Sounds small, a small technology.*	53%	*I think nano means like really tiny, and nanotechnology is like products made of really tiny things.* *I think that nano or nanotechnology means that you're using technology that uses really small technology.*
Understands size as too small to see	13%	*A word for small or a microscopic technology or tiny thing you can't really see.* *A very small thing you can't see.*	47%	*I think that nano means something that is too small to see with the naked eye.* *It's something so small you can't see it without special equipment.*

In the pre-interview, none of the viewers brought up a property of matter, whereas in the post-interview significantly more (50%)[8] noted something about strength, weight, color or structure (see Table 5). Answers may not be scientifically accurate but do show an expanded schema for nanotechnology.

Table 5. Understanding of Properties Related to Words "Nano or Nanotechnology" (N = 30)

Category of Response	% Pre	% Post	Examples of post answers
Notes something about a property of matter	0%	50%	*A thin material that makes things stronger.* *Something tiny or small so that you can't see it, it is microscopic but is very strong and is thin as paper.* *Something very small, light and strong.* *Something that holds strong like a stick. It is very very small.* *A small object that is used to put in things to make it light, and it can have color in it to make changes.* *Kind of like atoms, like a form with atoms to make a special shape or color.*

After answering the post-viewing question of what the words "nano or nanotechnology" mean, viewers were asked *"what in the show helped you think about nano or nanotechnology that way?"* and a follow-up probe of *"what particular part in the show helped you learn that?"* Responses were sorted into the four presentation formats of interest in this study: (1) the host explaining directly to the viewing audience; (2) the use of models to support content explanations; (3) onscreen kids doing hands-on activities; and (4) onscreen kids meeting with adults who show them something. Table 6 on the next page presents the percent distribution of responses for the four categories and examples of viewers' answers.

[7] McNemar One-Tailed Test of Paired Proportions, $p = 0.003$.

[8] McNemar One-Tailed Test of Paired Proportions, $p \leq 0.0001$.

Table 6 shows that almost half (47%) of the viewers noted the hands-on activities[9] as supporting their understanding of the words "nano" or "nanotechnology," particularly the hockey stick inquiry (40%). The hockey stick inquiry was mentioned by most of the Table 5 respondents who noted something about a property of matter in the meaning of "nano" or "nanotechnology."

The format of the onscreen kids meeting with an adult who showed them something was described by 37% of viewers. The carbon nanotube TEM image the onscreen kids saw in the Harvard lab was referenced frequently (33%) as clarifying the meaning of nano or nanotechnology. The TEM image was referenced by most of the Table 4 respondents who noted that nano was too small to see with the naked eye.

A small portion (10%) of the viewers recalled the chicken wire model as helping them understand the meaning of the words, and a few (7%) said the host's direct explanations helped. A few (7%) fifth graders were not able to identify a part of the show that helped them understand the meaning of the words 'nano' or 'nanotechnology.'

Table 6. Presentation Formats That Help Viewers Learn Meaning of Nano/Nanotechnology (N=30)

Presentation Format	% Post	Examples of answers
Onscreen kids doing hands-on activities	47% [40% Hockey stick inquiry 7% Butterfly wing inquiry]	*The hockey sticks, how the CNT was stronger and was hollow, but it turned out better than the other ones. When they went in and measured the weight and how strong it was for the force to break it.* *How they explained it helped. How they told us and found out it was the strongest hockey stick for nanotubes, and the nanotube hockey stick was strongest, and it was hollow.* *When they showed what it does, not just explained it, they showed what is does and what it can do. The bubbles and putting stuff on the butterfly wing.*
Onscreen kids meeting with adults who show them something	37% [33% Hockey stick image 10% Wing Image]	*You know how they took the hockey sticks to the guy who had the really big microscope and they took a little piece off, and they put it in the holder, and how they showed us what the nanotubes looked like, and how they looked really tiny.* *About the hockey sticks. Like how they couldn't see the nanofiber in the hockey stick and how they needed a really strong microscope.* *When they looked at the products and showed how they were really tiny, like the little wire on the screen of the microscope.* *I think that butterfly part with the wings and the different layers. I didn't really know about that before and it was kinda cool to see.*
Use of models to support content explanations	10%	*The part where they were at the museum place, and the guy was showing them how the chicken wire could hold it up, and then they tried the flimsier one and it didn't work.* *Like the examples they showed like the chicken wire thing.*
Host explains directly to audience	7%	*The main guy who was talking about it, Eric. He showed what a nano could do and how it helped. And when they showed the elevator it told how it was small and thin and strong.*
Category not clear	7%	*Them talking about it with examples.*

[9] The four presentation format categories are color coded in text and tables that refer to formats.

Understanding That Structure Inside Can Impact Strength of Object

Significantly more children in the post-viewing interview could explain how the structure inside something can influence the strength of an object, referencing nanotubes or molecular structures. Two presentation formats contributed the most to understanding: the "onscreen kids hands-on activity" with hockey sticks and the chicken wire "model."

Before viewing the program, the children were asked:
"How something is structured or made on the inside can change the strength of the object. Give me your best guess about what you think that statement means – how something is structured or made on the inside can change the strength of the object?"
After viewing, they were similarly asked: *"The show said that how something is structured on the inside can change the strength of the object. What does that statement mean – how something is structured on the inside can change the strength of the object?"*

Viewing the program significantly improved the fifth graders' ability to verbalize an understanding that the structure inside an object influences the strength of an object. Prior to seeing the program, 28% of the children made reference to the structure of a bridge, a building, or a body's skeleton; whereas after viewing, 55% of the sample referred to the structure of nanotubes or molecular structure.[10] (see Table 7 on the next page). The remainder of the sample either noted that the solidity or strength inside relates to strength of the object (31% Pre; 21% Post) or could not provide any relevant answer (41% Pre; 24% Post).

[10] McNemar Test of Paired Proportions, $p = 0.02$.

Table 7. Understanding that Structure Inside Can Impact Strength of Object (n = 29[11])

Category of Response	% Pre	Examples of pre answers	% Post	Examples of post answers
Reference to structure or shape of body skeleton, bridge, or building [Pre] or to nanotubes or molecular structure [Post]	28%	*It's kind of like a human. We humans need bones, and we need a spinal cord, that inner structure holds us up. Without that, we'd be a blob.* *It means like if you are building a bridge how the beams would be placed could change whether or not a car driving across the bridge would make it across or not.* *Like a building, depending on its structure, if it's good or bad, like if it's supported badly, it doesn't have a good structure.*	55%	*If something is in a nanotube, if it was flat, it would bend more, but if it was circular, it could hold more weight.* *If something is tube shaped, it has strength all around it, and if it were flat, it would be flimsy.* *When they were making the elevator, how it was really thin, but the string of the elevator could not break under its own weight. So it means that the metal tubes, even though they are really small, they can hold a lot of weight.* *How structure is formed with tiny molecules, like the lead that could break easily, but the diamond was structured better, and it was almost indestructible.* *It means that depending on how the molecules are shaped on the inside, it may change the strength. If the shape is a certain way, it might make the object stronger or weaker.*
Solidity or strength of inside relates to strength of object	31%	*How squishy or soft or hard it is.* *It means if something is jello-y on the inside, the outside isn't going to be very strong.* *How strong the thing is on the inside can affect or make it different on the outside*	21%	*Like if something is really compact, it will be stronger.* *If it is solid or if they are close together made of different materials.* *If it's strong on the inside, it may be strong on the outside.*
No relevant understanding	41%	*I really don't know.* *If something is well made, it would be interesting to a lot of people.* *How everything affects each other or something like that.*	24%	*I didn't get that. They said it made things stronger, but I didn't get how that worked.* *I don't remember really.*

[11] Inadvertently one viewer was not asked the post question.

After answering the post-viewing question about structure and strength, viewers were asked *"what particular part in the show helped you learn that?"* or a follow-up of "*what in the show helped you think about how changing the inside structure changes the strength of an object?"* Responses were sorted into the four presentation formats of interest in this study. Table 8 presents the percent distribution of responses for the four categories and examples of viewers' answers.

Table 8 shows that 55% of viewers noted the hands-on activities of the hockey stick inquiry as supporting their understanding of the relationship of interior structure to strength. One-fifth (21%) of the viewers recalled the chicken wire model as helping them understand. A small portion (3%) said the host's direct explanations helped, although this category could be increased to 9% with the addition of the space elevator challenge question, which Eric discusses in three parts across the program. In the study design and procedure, this 3-part segment was not included in the category of "host's direct explanations."

Table 8. Presentation Formats That Help Viewers Learn About Structure and Strength (N = 30)

Presentation Format	% Post	Examples of answers
Onscreen kids doing hands-on activities	66% [55% Hockey stick inquiry 10% Butterfly wing inquiry[12]]	*Probably how they compared the three different types of hockey sticks and how they had different structures, and the nanocarbon tube one was strongest, and that helped me.* *The hockey stick, how the CNT one, it showed how it could be stronger with the nanotubes.* *When they were testing the hockey sticks, how the CNT stick was stronger than the rest and it held the most weight.* *The butterfly wing when they put the acetone on.*
Use of models to support content explanations	21% Chicken wire model	*When they used the bowling ball and the chicken wire, they used the same thing but just rolled it up in different ways. That made it clear to me.* *When they made the tube out of chicken wire and then they put it out flat.*
Host explains directly to audience	3%	*When Eric was like comparing the shapes of structures.*
Challenge question about space elevator[12]	6%	*The part where they talked about elevators.*
Category not clear	3%	*I can't think of a part because it wasn't clear to me.*

Of the 55% of fifth graders who referred to nanotube structure or molecular structure in their post-interview (see Table 7), 44% noted the hockey stick inquiry as contributing to their understanding, 38% described the chicken wire model, and 18% mentioned Eric's presentations.

[12] The butterfly inquiry is about structure and color, not structure and strength

Understanding That Structure Inside Can Impact Color of Object Outside

Significantly more children in the post-viewing interview could explain how something is structured on the inside can change the color of an object outside, referencing light reflection. The presentation format that contributed the most to understanding was the "onscreen kids hands-on activity" with butterfly wings.

Before viewing the program, the children were asked:
"How something is structured or made on the inside can change the color on the outside. Give me your best guess about what you think that statement means – how something is structured or made on the inside can change the color on the outside?"
After viewing, they were similarly asked: *"Eric said that how something is structured on the inside can change the color on the outside. What does that statement mean – how something is structured on the inside can change the color of the outside of the object?"*

Viewing the program significantly improved the fifth graders' ability to verbalize an understanding that the structure inside an object influences the color of an object. Those who made reference to light reflection as a function of structure included 3% in the pre-viewing interview and 46% in the post-viewing interview.[13] (see Table 9 on the next page). The remainder of the sample could not provide a relevant answer (97% Pre; 54% Post).

[13] McNemar Test of Paired Proportions, $p = 0.0001$.

Table 9. Understanding that Structure Inside Can Impact Color of Object (N = 30)

Category of Response	% Pre	Examples of pre answers	% Post	Examples of post answers
Reference to light reflection as a function of structure	3%	*It can change how the light hits it.*	46%	*It means that some things have pigment and some are iridescent with ridges and light reflects off of them, the butterfly part in particular.* *Well, like the butterfly, you have ridges and it would only reflect a certain color of the light.* *Well, it's the atoms have little ridges, and it depends if the space in between them will change color, and if it is not filled up, it won't change color.*
Reference only to pigment and iridescence with no relevant understanding	0%	-	13%	*It means that if it was iridescent or pigmented, it could change color.* *It means like with pigments, and I don't really know how to explain it, - the pigments and the iridescence and the butterfly wings.*
Inside color shows through to the outside	23%	*I think that depending on the structure, like if it's clear, then the inside structure will change the color on the outside.* *Like maybe if something on the inside is a certain color and the outside is clear.*	13%	*If something has an inside structure that is colored, then it will change the color of the outside structure.* *That if something is strong on the inside, it may be a color representing it's strong on the outside.*
Chemical changes	7%	*I think it means, for example, how it digests the food, as to do with the colors, for example flamingos, because they eat shrimp then they turn pink.* *I think that means, well, this one is sort of like a plant like cytoplasm, or I forgot what, something in a plant cell that gives the plant its green color.*	0%	-
No understanding	67%	*I would only guess that it can somehow change in color, and maybe just get even smaller.* *The inside can change the outside color.*	27%	*The show didn't say much about this. I think they talked about the color, but I don't remember hearing how it changed this.* *I'm not sure about that. I didn't really get it. I just see that things can be different colors when nano is there.* *Butterflies can change color.*

After answering the post-viewing question about structure and color, viewers were asked *"what particular part in the show helped you learn that?"* or a follow-up of "*what in the show helped you think about how changing the inside structure changes the color of an object?"* Responses were sorted into the four presentation formats of interest in this study. Table 10 presents the percent distribution of responses for the four categories and examples of viewers' answers.

Table 10 shows that a large majority (83%) of viewers noted the butterfly wings hands-on activity as supporting their understanding of the relationship of interior structure to color. A small portion (10%) described as helpful the onscreen kids meeting with adults who showed them the SEM butterfly wing image, and one child (3%) said the host's direct explanation about the nanofiber shirt helped.

Table 10. Presentation Formats That Help Viewers Learn About Structure and Color (N = 30)

Presentation Format	% Post	Examples of answers
Onscreen kids doing hands-on activities	83% Butterfly wing inquiry	*How they used the butterfly wings and how they changed color with the acid thing. That made it clear to me.* *For the butterfly, if it is built differently on the inside it changes the color. By looking at it at one angle, it changes the color, but then looking at it another way changes the color. If you change the angle of the wings, it changes the color.* *When the sun would reflect onto the wing, it would give off a certain light and what they put onto the butterfly wings, the one liquid, it would change what color it would be. The butterfly wings were structured pretty much differently depending on what kind it was.* *Like what is used on the inside, like if it is pigment, then it won't change color, but if it is iridescent, it will change how it looks on the outside. How they did that with the butterflies. How if it is iridescent, it can change and how it can change depending upon how it was formed.*
Onscreen kids meeting with adults who show them something	10% Blue Morpho SEM wing image	*The part when they went to the lab with the big microscope where they went and looked and zoomed in to see those ridges on the butterfly.* *When they went to the museum to look at the butterfly wing, it showed you the ridges.*
Host explains directly to audience	3% Nanofiber shirt	*I just remembered about the shirt like using small electrical impulses because of the small tiny nanotubes, when you shock it, it sort of changes color.*
Category not clear	3%	*I don't think there was anything that taught me that.*

The 46% of fifth graders who appeared to understand the relationship of structure and color (see Table 9) noted two presentation formats as helpful: onscreen kids doing hands-on activities and onscreen kids meeting with adults who show them something.

Presentation Formats That Showed How Nanoscale Structures are Used in Products

A large majority of viewers could recall current or potential products using nanoscale structures. This information was presented effectively through two formats: "onscreen kids doing hands-on activities" and "host explains directly to audience."

After viewing, researchers asked: "*Some parts of the show explained how nanoscale structures are used in products. What part do you remember that explained this idea – how nanoscale structures are used in products?*" Two-thirds (67%) of viewers noted that sports equipment were nano products, recalling things shown in the hands-on hockey stick inquiry (see Table 11).

Another 33% recalled the host's direct explanations. One-fifth (20%) mentioned Eric's nanofiber shirt. Host Eric also showed products that use the nano term, saying: " *...have you ever noticed how much the word "nano" shows up these days? I mean, there are ads for nano hair dryers, shampoos, umbrellas, there's even a car named Nano. I wonder how many of these things actually use nanotechnology?*" Some (13%) of the audience were misled into thinking that these items use nanotechnology, despite Eric's question of doubt.

Additionally, 17% noted the space elevator challenge question, and 17% of viewers mentioned food, prompted by the segment "Hey, Wait a Nanosecond," which shows interviews with kids answering the question: Would you want to know if a product was made with nanotechnology?

Table 11. Formats Helping Viewers Learn About Products Using Nanoscale Structures[14]

Presentation Format	% Post	Examples of answers
Onscreen kids doing hands-on activities	67% Hockey stick inquiry	*The hockey stick. It made the stick faster and stronger.* *I think the hockey stick, like the fibers of the hockey stick inside.* *When the two boys were thinking of all different kinds of products like the skis, the bikes and the bats, stuff like that.* *Like that it's used in hockey sticks and sports equipment, so you can play sports and that's how they make it.*
Host explains directly to audience	33% [20% Shirt; 13% Products with name of nano]	*In one of them, he said that the new shirt that could change by using the nano technology could change the color of the shirt by hitting the switch.* *Where they were showing like the shirt, how electricity changed the colors.* *He said that a car is named nano something and iPod is name iPod nano.* *Like when he was talking about the products that used the word nano in them. There was a car, iPod, shampoo, tent, umbrella, and something else I don't remember.*
Challenge question about space elevator	17%	*The space elevator. The elevator was thin and strong at the same time.*
Hey, wait a nanosecond[15]	13%	*The kids were in the photo booth and they were talking about what they would want it in, like they wouldn't want it in their food.* *When the children were talking about it, and how they would say that they don't want it to be in the food, but they want it to be in the products and they want to know about it.*
Don't recall	3%	*I don't remember.*

[14] Viewers could describe more than one product.

[15] This segment does not fall into one of the four presentation formats of interest to this study.

Presentation Formats That Showed How Scientists Work at the Nanoscale

When asked what part of the show helped them understand something about how scientists work at the nanoscale, 80% of viewers recalled scientists looking for nanoscale structures with large microscopes. This information was effectively presented through the format: "onscreen kids meeting with adults who show them something."

After viewing the program, viewers were asked: "*The show explained how scientists did research at the very small nanoscale. What part of the show helped you to understand something about how scientists work at the nanoscale?*" Most (80%) of the viewers recalled the format where onscreen kids meet with adults who show them something (see Table 12). In this program, scientists used big and sometimes bigger microscopes to see the hockey sticks and butterfly wings at the nanoscale.

Another 17% recalled the scientist profile and her search for a nanoscale glue equivalent to the mussels' glue. This segment does not fall into one of the four presentation formats of interest to this study.

Table 12. Presentation Formats That Help Viewers Learn About How Scientists Work at the Nanoscale (N = 30)

Presentation Format	% Post	Examples of answers
Onscreen kids meeting with adults who show them something	80% 63% Hockey stick microscopes; 7% Butterfly microscope; 10% microscopes generally	*How they used all the microscopes, electron microscopes, to see inside the sticks. It was easy to see and easy to see a difference.* *When it showed they were using the giant telescope.*[16] *One was like a helium telescope.* *When they showed the telescope, and it wasn't even big enough to work, and then they showed the really really big one, and that one worked.* *I think it was like with the butterfly and how they studied them with microscopes. I was interested to see what happens and it was cool to watch.* *They used the giant magnifying machine.*
Scientist profile: mussel scientist[17]	17%	*When they were trying to find out about the mussels, and they would have to use microscopes to get good readings about the glue that they had.* *In the lab they were studying the mussels because they were trying to make the same glue, and they said that if they made it like a band aid, it would be an everlasting band aid. The glue and the nano is very strong, and they can hold stuff really easily, and they are both small.*
Don't recall	3%	

[16] Children frequently confuse the terms microscope and telescope.

[17] This segment is not included in any of the four presentation formats of interest in this study.

How Presentation Formats Support Learning

Viewers explained how different segments within the four presentation formats helped them learn something. With respect to the hands-on activity format, the important characteristics were showing rather than telling the viewer critical information and clearly demonstrating procedures and results of the activities. Content that viewers could relate to and activities that they could actually perform themselves were also important to viewers' perceptions of their learning. The format where on-screen kids meet with adults who show them something was effective because the scientists' explanations were age-appropriate and clear, letting viewers learn along with the onscreen kids, and because viewers obtained access to adults' microscopes to see the unseen. Similar characteristics were deemed important in the hosts' direct explanations to the viewing audience: Eric showed things; his explanations and comparisons were clear; and viewers connected to the content. Viewers felt that the format of using models to support content explanations was effective because experiments or procedures clearly demonstrated relationships or comparisons.

When asked to choose a segment that contributed the most to their learning, 43% chose from the models format, 23% from hands-on activities, 20% from adults showing something to onscreen kids, and 13% from the host's format of explaining directly to viewers. According to viewers, the critical characteristics contributing to learning in these choices were showing rather than telling and clear demonstrations of comparisons, relationships, procedures or results.

After eliminating models from the list of formats, 50% of viewers identified as most helpful for learning the format of watching onscreen kids doing something themselves, because the kids showed viewers things and because viewers could relate to and identify with the onscreen kids and their activities. One-third of viewers preferred the format of watching adults present information because the adults were professionals who had more information and more accurate information. One-fifth of viewers opted for Eric's presentations because the host repeated explanations and explained things clearly.

The second half of the post-interview explored more specifically which of the examples within the four presentation formats viewers felt was the most effective in helping them learn and why. Interviewers introduced this section of the interview by saying: "*The show used a variety of television techniques to help you learn. We want to know what television techniques helped you learn and why you think they were effective in helping you learn."* For each of the four presentation formats, the interviewers showed photos of segments and asked viewers to choose which segment helped them to learn the best and why. See Table 1, pages 2-4, for thumbnail versions of segment photos.

On-screen kids doing hands-on activities. The researchers showed photos of four examples within the "hands-on activities" format and asked: "*The kids onscreen sometimes did some*

hands-on activities like measuring slap shots with different hockey sticks, or measuring the weight and strength of different hockey sticks, or looking at the color of bubbles, or changing the colors of butterfly wings. Here are four photos from segments where the kids did hands-on activities. Which of these segments do you think helped you to learn the best? [and in reference to the child's choice] *How was this hands-on activity effective in helping you learn something?"*

The attribute highlighted most frequently with respect to the hands-on activities format was that the segments showed the viewer critical information rather than just telling the viewer. Secondarily, the viewers felt the format clearly demonstrated the procedures and results of the activities, reinforcing the learning outcomes. A few children also felt they could carry out the activity themselves, or they made a personal connection to the content. The viewing group spread their choices across all four segments, as shown in the percentages below.

- ✶ 30% chose "measuring the weight and strength of different hockey sticks."
  - The attribute noted most frequently was that the segment showed the results visually:
    It was helpful because you could see how much weight it would take, because it would be kind of hard to imagine that in your head, so it was good that it showed you.
    It showed how it worked and how it was strong. You could visually see it.
  - Viewers also felt the procedure demonstrated clearly the relationship between structure and strength:
    I think it helped me learn because it took the most pressure to break the wooden stick, but the one with the most strength was the CNT stick.
    It sort of made me understand how when they broke the hockey sticks, even though it was thinner, it was still pretty strong.
  - Children connected to the content:
    Because I made a connection to it because I play hockey and I have a CNT stick. I used to have a composite stick and a wood stick.

- ✶ 30% chose "changing the colors of butterfly wings."
  - The attribute noted most frequently was that the segment showed the results through the color changes:
    Because they looked at the acetone and saw how the color changes really fast, and it didn't take like a few hours to affect it.
    Because it showed you.
  - Viewers also felt the procedure demonstrated clearly the result:
    When you have the ridges, and you close the lines, it affects the color of the wings. It was the most clear. It had the least confusing stuff.
    For the butterfly, they got 4 samples, and they were trying to do pigment and iridescence. And they said if you pour water [acetone] *on one, and it doesn't change color, it was pigment, but if you poured water on it, and it did change color, it was iridescent. That was clear because they told you at the beginning and they told you what would happen, so when they had 4 samples and tried it, everything was basic and clear.*
  - Children connected to the content:
    I am kinda interested in butterflies. I think they are kinda neat, and it was kinda cool to find out how the pigment and the iridescent and how like both of it could be in one

butterfly or one could be one. I think that was pretty cool.

- ✶ 27% chose "measuring slap shots with different hockey sticks."
  - The attribute noted most frequently was that the segment showed the results through the graph:
    It showed me instead of just telling me.
    They would show a graph and what the average speed was instead of just telling it out loud.
  - Viewers also felt the procedure demonstrated clearly the comparison:
    The measuring part was easy to see, and it was clear.
    They made it clear and showed how it was different by using a comparison.
  - Children felt the activity was something they could do:
    I mean I would do that. So seeing something I would do.

- ✶ 13% chose "looking at the color of bubbles."
  - The attribute noted most frequently was that the segment showed the results through the color changes:
    The bubbles, because it showed that if it turns colors, it is iridescence. The way they explained it was good, and it was interesting to watch the change take place.
  - Viewers also felt the procedure demonstrated clearly the comparison:
    It showed how iridescence worked and how the butterfly wings and bubbles are the same, like a comparison. Seeing things like that were helpful.
  - Children felt the activity was something they could do:
    I thought that was helpful if you didn't get what they said, you could just do it as an at-home project. Just with some adult supervision.

On-screen kids meet with adults who show them something. The researchers showed photos of two examples within the "adults who show something" format and asked: "*Sometimes the onscreen kids met with adults who showed them something, for example, they looked at the microscopic pictures of carbon nanotubes or looked at microscopic pictures of butterfly wings. Here are two photos from segments where adults showed the kids something. Which of these segments do you think helped you to learn the best?* [and in reference to the child's choice] *In the segment you chose, the onscreen kids got information from an adult. How was that effective in helping you learn something?*

Two characteristics were highlighted with respect to the format where "adults show onscreen kids something." Viewers felt that the scientists' explanations were age-appropriate and clear, letting them learn along with the onscreen kids. Viewers also felt that access to the adults' microscopes was important because that permitted them to see how small the nanoscale is. With respect to which segment helped learning the best, the viewing sample split their votes between the two segments, and there was no gender difference even though carbon nanotubes featured boys onscreen and butterflies featured girls.

- ✶ 50% chose "looking at microscopic pictures of butterfly wings."
  - Viewers most frequently noted that the scientist's explanations were effective because

they were clear and the viewers could learn along with the onscreen kids:
It was effective because he was educated about these type of things, and he knows a lot, so he could tell the kids and that can make me learn, because the kids are just like me, and they want to learn too.
He gave feedback that was easy to follow and understand, and he explained what some of the words meant, and he was better at explaining. I understand things better.
It was clear, and it had more easy explanation. It wasn't hard to understand.

- Another attribute described as effective in helping learning was the ability to see how small the nanoscale is:
Because the magnification was stronger with the butterfly wings. It helped me because I could actually see more detail of the structure.
It shows how small each part is, how it's invisible to the naked eye, can only see it close up. There is actually more going on than what you can see.

✶ 47% chose "looking at microscopic pictures of carbon nanotubes."
- The attribute noted most frequently as effective in helping viewers learn was the ability to see how small the nanoscale is:
Because it showed you how small the nanotube really was and different.
Because the adult had fancy technology, so you could see the nanotubes because you could normally not see them.
They get a closer look than they would have on their own.

- Viewers also felt the scientist's explanations were effective because they were age-appropriae and clear and the viewers could learn along with the onscreen kids:
Because as I watched him talking, it helped me learn something too, like the boys.
The adults were helpful explaining. They made it clear. I think it was the way they explained it, how with the nanotubes they showed a picture of the electron microscope, and they asked the kids what they thought were the nanotubes, and they were much smaller than they thought.
When the scientist explained this, it was easy for me to get and it wasn't that complicated.

✶ 3% could not decide because *both used microscopes and both showed you what's on the inside, so they both helped me understand it, so there is not a better one.*

Host explains directly to viewing audience. The researchers showed photos of three examples of the host format and asked: "*Sometimes Eric explains things to the viewing audience, for example, showing carbon molecules, or spider webs, or nanofiber shirts. Here are three photos from segments where Eric did presentations. Which of these segments do you think helped you to learn the best?* [and in reference to the child's choice] *How was this explanation by Eric effective in helping you learn something?"* [18]

[18] The space elevator challenge question was presented in three segments, and in developing the procedure, it was decided not to include the challenge in the category of the "host explaining directly to the viewing audience;" thus, an image from the challenge question was not among the examples respondents saw in the second half of the interview.

Numerous characteristics were highlighted with respect to Eric's presentations. Viewers felt that Eric showed the things and that his explanations and comparisons were clear and sometimes funny. Viewers also connected to the content of changing shirt color and spider web strength. The viewers split their votes among the three segments as to which helped learning the best:

- 40% chose "carbon molecules."
  - Viewers most frequently noted that the Eric's segment showed the size and arrangement of molecules:
    It showed how the molecules were built and put together to make the nanotubes.
    It showed how small the molecules are and how they were used to build things.
    Because it showed you how the carbon molecules are arranged in certain objects like the diamond and the graphite.
    Because it showed the carbon molecules and they showed that it can make graphite and it can make diamonds, so that one helped me learn the most.
  - A few viewers added that the segment was funny:
    I think he ended funny, but before that you could really learn something – talking about diamonds and how it could scratch something. So it was funny and interesting.
    It told me that the molecules can be formed in different ways to do different things. It was good and funny and all.
- 30% chose "nanofiber shirts."
  - Viewers noted that Eric's explanations were clear:
    He explained more about the nano. He was good to listen to and follow. He explained it better, and he got my attention.
    The shirts one because he explained, and he taught more about nano, so we know what it means, and he told how the shirt worked, and how you just have to turn a switch on.
  - Children connected to the content:
    It was really interesting, and I like technology a lot. I was always thinking it would be cool to change my shirt if I didn't like it, and this showed me that could really work.
    That's pretty cool, like a shirt turns a different color. It kinda taught me that when nano and electricity mixed together, I guess it could change the color. That's pretty amazing for a shirt to turn blue to red. That is pretty shocking. I thought that was pretty cool.
  - A few viewers added that the segment was funny:
    It's my favorite color! The nanotubes helped change the boy's white shirt to a fascinating blue color. Eric helped because he made a few jokes about it.
- 30% chose "spider webs."
  - The attribute noted most frequently as effective in helping them learn was the comparison of spider web strength to steel:
    Probably it was effective because he said that it was stronger than steel, and that shows that the structure of something can really make a difference of how strong something is.
    That he said the spider web fivers were really strong, and they were stronger than steel..
    They get a closer look then they would have on their own.

- Children also connected to the content, because they are familiar with spider webs:
  The spider web you already know about and are common.
  It was a common thing, something I didn't know about something that I have known about, so it was more interesting.

Use of models to support content explanations. The researchers showed photos of two examples of the model format and asked: "*Sometimes segments used models to help you learn, for example, the museum's balloon carbon nanotube or the chicken wire to model shape and structure of a nanotube. Here are two photos from segments where models were used. Which of these segments do you think helped you to learn the best?* [and in reference to the child's choice] *How was this model effective in helping you learn something?'*

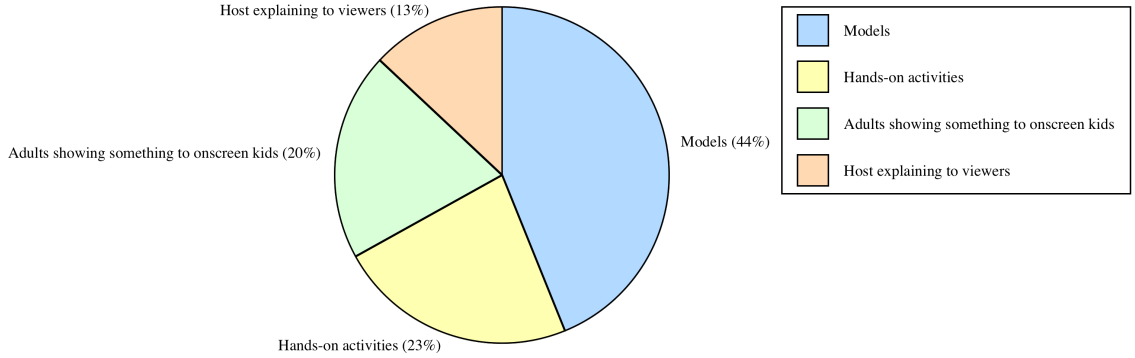
Viewers clearly felt that the chicken wire model was the most effective of the two examples because **the model clearly demonstrated the relationship between structure of the wire and strength**.

- 96% chose "chicken wire model."
  - All viewers in this group felt the procedure demonstrated clearly the relationship between structure and strength:
    It was effective because it really showed you in an example. And in the balloon, it just showed you what it would look like, but in this one [chicken wire]*, it proved why.*
    Because the balloon model, they didn't do an experiment, but they did with the chicken wire, and you could really see the effect.
    They did the experiment, and the adult told them how the flimsy one can't support the bowling ball, and I think because they did an experiment, and the other one [balloon model] *was just showing. I would do that experiment if I was trying to figure something out.*
    Because they were doing tests on it, and it showed when it is tube-shaped, it was stronger, and when it was flat, it was flimsy.
    It showed me that how it was rolled in the first way was weak, but how it was rolled the other way, the bowling ball stayed. This one [chicken wire model] *they explained more about the nanotubes, and this one* [balloon model] *they just showed it and that's all.*

- 3% chose "balloon carbon nanotube model." This viewer said that she did not understand the chicken wire explanation.

Which of four formats helped learning the most. After discussing each of the four formats as explained in the previous pages, the children picked from among their four chosen photos the one from which they thought they learned the most and explained again what it was about the segment and its television techniques that helped them learn. Figure 1 below shows that viewers most frequently chose from the models format (44%), picking the chicken wire model of nanotubes. One-quarter (23%) of the sample chose segments in the hands-on activities format, including measuring slap shots (3%), measuring weight and strength of sticks (10%) and changing colors of butterfly wings (10%). One-fifth (20%) of the sample chose segments when the onscreen kids visited adults who showed them carbon nanotubes (7%) and butterfly wings (13%). A smaller portion (13%) picked segments when the host, Eric, explained to viewers something about carbon molecules (7%), spider webs (3%) or nanofiber shirts (3%).

Figure 1. Formats which helped learning



With respect to all four format categories**, the critical attribute contributing to learning was showing something visually**; for example:

- Models:
  The chicken wire, they showed what the whole show is really about.
  Cuz they showed me how something is structured can affect the strength that it can hold.
  It showed me how a carbon nanotube was shaped and how it was stronger than something that wasn't shaped like a carbon nanotube.
- Hands-on activities:
  Really seeing them do something.
  It was cool to see the colors changing when they put the stuff on.
- Adults showing something to onscreen kids:
  It was really cool to see inside a hockey stick.
  This one showed what they looked like in the butterfly wings and how they were spikes and how there is space between them.
- Host explaining to viewers:
  It just shows you what makes up molecules and like how atoms are inside molecules.
  It's a good way to show that we can mimic nature.

The second most frequently noted attribute, related to two of the four formats, was clear demonstration of comparisons, relationships, procedures or results; for example:

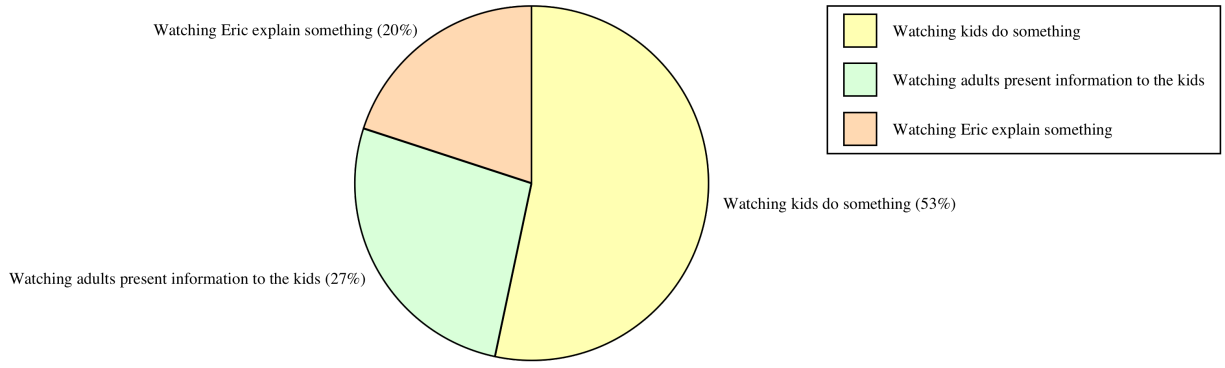
- Models:
  Because they did an experiment of how they did it wrong, and then did it right. They compared the two- why it was wrong and why it was right.
  Because it compared the different ways the structures were made and how that could affect the outcome, you know, actually showing the data.
- Hands-on activities:
  They showed me what would happen when they used the different sticks so I could compare. They made it clear and showed how it was different by using a comparison.

Which of three formats helped learning the most. After choosing a segment photo for one of the four formats, the "models" format was removed from the interview. Interviewers then asked children to choose from the remaining three formats: *In this show, sometimes you watched the kids doing something themselves, sometimes adults presented information to kids, and sometimes the host Eric explained something to the viewer. Which of these techniques do you think had the most impact on your learning? Why?*

Figure 2 indicates that viewers retained the rank order from Figure 1 of the three format choices. Half of the viewers (50%) identified as the most helpful for learning the format of watching onscreen kids doing something themselves. **The children reiterated that this format showed them things rather than telling, but viewers also introduced a new attribute in their interviews: viewers could relate to and identify with the onscreen kids and their activities**; for example:

Because you could really relate to what they were doing.
They did stuff. They did experiments that most kids can relate to because that made it easier for me, so I could connect to it.
It had the most impact, because the kids are just like me, and they do things, and they'll go to science labs, and they'll actually like explain how they do it.
Because I could do that, since they are my age, and I could easily do that at home.

Figure 2. Formats which helped learning



One-third of the viewers (30%) identified the format of watching adults present information as the most helpful for learning. Viewers felt that the **adults were professionals who had more information and more accurate information;** for example:

With the butterfly wings, they kinda go into more detail. They tell you how the little gaps make the color on the outside, and they also tell you how big the gaps are.

Because the adults are professional scientists, and they know how their topics works, and they can show the kids how a product works, and they can give the scientific explanations.

You know how the kids would assume something was right, but the adults would come and show facts and you would know they were right.

Because they did this for years, so they actually know what they are saying a lot. The adults knew a lot that I didn't know, so they presented and helped the kids learn more about everything too and helped me learn about nanotechnology I never knew about.

Because they knew the most about it, and they could explain it well.

One-fifth of viewers (20%) chose the format of watching Eric explain something as the most helpful for their learning. Viewers felt that **Eric repeated explanations and explained things clearly;** e.g.,

The kids showed you something and then Eric went back and reviewed it a little bit and showed you a little extra.

Eric was good at explaining, and that's where I got most of my meanings from.

I like how Eric was explaining things, because he went deep down into how it works, and he gave examples.

Importance of Nanotechnology in the Future

All viewers concluded that nanotechnology will be very or somewhat important in the future. The children felt that nanotechnology will make life easier, that we can build or invent new things, use fewer resources, save money, or apply the technology in many different areas.

At the end of the interview, viewers were asked how important nanotechnology is going to be in the future and why they think nanotechnology will be important. Almost all (87%) felt that nanotechnology will be "very" important, and 13% said it will be "somewhat" important. Viewers provided a wide range of reasons for why they felt nanotechnology will be important:

- ✶ Nanotechnology will make life easier or better; for example:
  Because it will help make life easier and stuff.
  It will help us live better and help us improve stuff, so we'll not need so much stuff to do it.
  Because this is a new way that they found to make things, like with the mussels and the glue with band-aids, because that would be useful, and with the space elevator, it sounds like it would be useful in the future.

- ✶ With nanotechnology, we can build or invent new things; for example:
  I think it will be really important to discover information to help with the space station and help with building stuff.
  Because we're gonna need a lot of things to help us in the future, and they might be one of the resources we might need to build things.
  It can expand where we go so we can make houses on Jupiter or something, a city in the clouds or something.

- ✶ Nanotechnology can save resources; for example:
  It is a lot less expensive to use carbon nanotubes instead of steel, and you can put in some plastic and put that around cars instead of metal and that saves the raw materials.
  Because we'll want to make cars and airplanes stronger so they could use the nanotechnology for that, and we wouldn't have to have so much metal, we could just use plastic with mussel glue.
  It could probably help with the future hybrid cars. They are the only one that don't run on gas, so you don't ever have to go to the gas station ever again!

- ✶ Nanotechnology can save money; for example:
  If the economy stays really bad, you won't need to buy so many shirts. You can just change the color to whatever you want.
  It will help us save money instead of buying new things, so many things can be made to be less wasteful.
  It will help save money, because we can buy fewer shirts. It will help the economy and be more efficient.

- ✶ Nanotechnology can be used in so many different ways; for example:
  Remember how they said that there were many products that would have nano in them.
  Pretty much they can be using everything from nanotechnology, except for food because that would be pretty gross.
  Because a lot of things are starting to be made out of it. Without it, there won't be that much new technology.

RESULTS: *SMALL IS DIFFERENT*

Understanding of the Words "Nano or Nanotechnology"

Although three-quarters of fifth graders said they had heard of the words "nano or nanotechnology" before viewing *Small is Different*, seeing the show significantly expanded their understanding of the meaning of these words. Viewing the program significantly increased understanding that nano means a very small size but did not significantly increase the percentage of children who understood the nanoscale size as too small to see with the naked eye. Significantly more children in the post-viewing interview noted something about change in reactivity or color in their description. Viewers identified one presentation format as helping them the most: The format of "hands-on activities," in particular the soda explosion experiment and gold and silver nanoparticle inquiry, helped viewers to understand that changing size can influence reactivity or color.

Before viewing *DFTV Nano: Small is Different*, three-quarters (73%[19]) of fifth grade participants said they had heard of the words "nano" or "nanotechnology." Before viewing the program, the children were asked: *"Give me your best guess about what you think the words "nano or nanotechnology" mean?"* After viewing, they were asked: *"Now that you have watched this show, what do you think the words "nano or nanotechnology" mean?*" The goal of these questions was not to elicit a specific scientific definition but to assess how viewing the show might expand viewers' understanding of the terms.

Viewing the program significantly improved the children's ability to verbalize some relevant understanding about the terms, with half (50%) of the sample indicating no relevant understanding before seeing the program and 100% showing some relevant understanding after viewing[20] (see Table 13).

Table 13. Understanding of the Words "Nano or Nanotechnology" (N = 30)

Category of Response	% Pre	Examples of pre answers	% Post
No relevant understanding	50%	*Something about technology.* *Like it's about the computer.* *There is an iPod nano out, so it is probably some newer version of an iPod sort of thing.*	0%

[19] Same percentage as the *Structure of Matter* result.

[20] McNemar One-Tailed Test of Paired Proportions, as applied here, assesses the equality of before and after proportions for the same sample. $p \leq 0.0001$.

Before the program, 43% understood "nano" to refer to a very small size; whereas after viewing the program, a significantly greater number of viewers (83%) described a very small size[21] (see Table 14). Before viewing, 7% understood the terms to refer to something that is too small to see with the naked eye; after viewing, 17% gave this category of answer, but these before-after proportions are not statistically different.

Table 14. Understanding of Size Related to Words "Nano or Nanotechnology" (N = 30)

Category of Response	% Pre	Examples of pre answers	% Post	Examples of post answers
Understands size as very small	43%	*Really really small technology* *I think it means small or tiny.* *Nano means small, and nanotechnology means small machines.*	83%	*It is something that is really really small.* *Nano means to make something really really small, even smaller than normal dust.*
Understands size as too small to see	7%	*Nanotechnology is a form of technology which studies microscopic machinery or organisms.*	17%	*Nano or nanotechnology are very small, not really viewable unless you use machinery to view.* *Something really small that you can't see without a microscope.*

In the pre-interview, none of the viewers brought up a property of matter, whereas in the post-interview significantly more (30%)[22] noted something about a change in reactivity or color occurring at the nanoscale (see Table 15). Answers may not be scientifically accurate but do show an expanded schema for nanotechnology.

Table 15. Understanding of Properties Related to Words "Nano or Nanotechnology" (N = 30)

Category of Response	% Pre	% Post	Examples of post answers
Notes something about a property of matter	0%	30%	*Something that can get really small that has a big reaction on things.* *Something that is really small and when you expose it to a force, it would have a large effect.* *I think nanotechnology means like little bits and pieces that can make big things like explosions.* *It means they are more likely to change since they are so small. When things are nanoish tiny, they can change.* *It means small things, like small things that change color, things like that.*

After answering the post-viewing question of what the words "nano or nanotechnology" mean, viewers were asked *"what in the show helped you think about nano or nanotechnology that way?"* and a follow-up probe of *"what particular part in the show helped you learn that?"* Responses were sorted into the four presentation formats of interest in this study (1) the host explaining directly to the viewing audience; (2) the use of models to support content explanations; (3) onscreen kids doing hands-on activities; and (4) onscreen kids meeting with adults who show them something. Table 16 on the next page presents the percent distribution of responses for the categories and examples of viewers' answers.

[21] McNemar One-Tailed Test of Paired Proportions, $p \leq 0.0001$.

[22] McNemar One-Tailed Test of Paired Proportions, $p = 0.002$.

Table 16 shows that two-thirds (63%) of the viewers noted the hands-on activities[23] as supporting their understanding of the words "nano" or "nanotechnology," particularly the soda explosion and gold/silver nanoparticles inquiries.

A small portion (10%) of the viewers recalled models as helping them understand the meaning of the words, and 10% said the host's direct explanations helped. The format of the onscreen kids meeting with an adult who showed them something was described by one viewer (3%).

The remaining children (13%) identified other segments of the show or the whole show as helping them understand the meaning of nano or nanotechnology. (See bottom rows of Table 16).

Table 16. Presentation Formats That Help Viewers Learn About Meaning of Nano/Nanotechnology

Presentation Format	% Post	Examples of answers
Onscreen kids doing hands-on activities	63% [30% Soda inquiry 27% Gold/Silver inquiry 3% Cookie inquiry 3% all]	*I think it was that soda explosion because it showed you, with like the big rocks and the pebbles and the sand, it showed you that the smaller particles, bigger surface area, the more power it had.* *When they showed the big rocks and the little ones. The nanosized bits had a bigger reaction on the experiment.* *How the gold and silver changed color by getting bigger or smaller. That surprised me. It was clear and all.* *When they were cooking the cookies and how there was not enough sugar for the small ones but there was enough for the big cookie.*
Use of models to support content explanations	10%	*When they were doing the blocks.* *The Marco Polo thing.* *The blocks and like when he said a dinner plate can change into a cheeseburger*
Host explains directly to audience	10%	*The baking soda* [antacid] *in the experiment of fizzy powder and stuff, how he crushed it down.* *Eric's saying things and explaining them. That's what I kept noticing.*
Onscreen kids meeting with adults who show them something	3%	*The flour part, where they showed it exploding. That was cool.*
Challenge question about propelling rockets?[24]	3%	*The challenge – that if it was broken down, it could be different. Like a roll of tinfoil isn't flammable, but when it's broken down, it's different.*
Hey, wait a nanosecond[25]	3%	*Like when the kids say it when they have a chance to talk, because it could be safe or unsafe.*
Zoomcab[26]	3%	*When they zoomed into the eyeball.*
Category not clear	3%	*Pretty much the whole show. I really can't think of one thing in particular.*

[23] The four presentation format categories are color coded in text and tables that refer to formats.

[24] In the study design and procedure, this 3-part segment was not included in the category of "host's direct explanations."

[25] This segment does not fall into one of the four presentation formats of interest to this study.

Understanding That Some Things Change a Lot When Nanosized

Significantly more children in the post-viewing interview could explain the statement that nanosizing something changes it a lot, referencing properties of reactivity or color. Two presentation formats contributed the most to understanding: the "onscreen kids' hands-on activities" and the "use of models."

Before viewing the program, the children were asked:
"When some things are nanosized, they change a lot. Give me your best guess about what you think that statement means – when some tings are nanosized, the change a lot."
After viewing, they were similarly asked: *"Eric said that 'when some things are nanosized, they change a lot'. What does that statement mean – when some things are nanosized, they change a lot?"*

Viewing the program significantly improved the fifth graders' ability to verbalize an understanding that nanosizing something influences its properties like reactivity or color. Prior to seeing the program, none of the children made reference to the properties of matter as a function of size, whereas after viewing, 47% of the sample referred to the reactivity or color results of nanosizing.[26] (see Table 17 on the next page). The remainder of the sample either noted only a decrease in size with no mention of properties (60% Pre, 47% Post), or a change in form (27% Pre; 7% Post) or could not provide any relevant answer (13% Pre; 0% Post).

[26] McNemar Test of Paired Proportions, $p \leq 0.0001$.

Table 17. Understanding that Nanosizing Can Change Something a Lot (N = 30)

Category of Response	% Pre	Examples of pre answers	% Post	Examples of post answers
Reference to property change, reactivity or color changes as a result of nanosizing	0%		47%	*It means that it can go from being big and bulky to small and being able to move, as if it was alive, basically its reactions change.* *When it is small, it changes the way it reacts to heat or soda.* *He means that they can be either unstable or reactive to different chemicals than if they were full-sized.* *Like with the gold and the silver, it changed the color cuz they were nanosized, and it was breaking it down into different sizes which somehow affects it to change the color.* *Like when the thing gets nanosized, it gets smaller and then it can change color or other properties, like get different in some way.*
Reference to change in size with no change in property	60%	*Nano-sized, kind of like saying, microscopic, shrunk down to microscopic sized. Scientists use that to go into bodies.* *It means really small, becomes a lot smaller than it already is.* *It means like that it gets smaller. It's smaller than usual things are.*	47%	*When things are big, they crush them, and they like turn into smaller sizes.* *They are much smaller than they would be. If you just have something normal, it's pretty big, but then if you go to nano size, it like gets really, really small.* *It means that they change and make it smaller.*
Reference to changing form	27%	*Caterpillars change a lot, so maybe like a caterpillar would be nanosized.* *Maybe that they metamorphosized?* *Maybe evolve over time.*	7%	*It can change into different shapes like the plate turns into a mini hamburger.* *It could be like I'm going to say I can break this pen down to nanosize and it's going to be like that cup over there.*
No understanding	13%	*Maybe dissected.* *I have no idea.*	0%	

After answering the post-viewing question about the changes of nanosizing, viewers were asked *"what particular part in the show helped you learn that?"* or a follow-up of "*what in the show helped you think about nanosized things that way?"* Responses were sorted into the four presentation formats of interest in this study. Table 18 presents the percent distribution of responses for the categories and examples of viewers' answers.

Table 18 shows that 47% of viewers described the hands-on activities as supporting their understanding that size changes may change properties. One-quarter (23%) of the viewers recalled models as helping them understand, and a small portion (7%) said the host's direct explanations helped. No one described segments where the onscreen kids met with adults who showed them something.

Of the 47% of fifth graders in Table 17 (on previous page) who referred to property changes in their post-interview, most (20%) noted the gold and silver nanoparticle inquiry as contributing to their understanding, 10% described the soda inquiry, 10% the aluminum rocket fuel challenge, and 7% mentioned Eric's presentations.

Table 18. Presentation Formats That Help Viewers Learn About Size and Properties (N = 30)

Presentation Format	% Post	Examples of answers
Onscreen kids doing hands-on activities	47% [23% Soda inquiry 20% Gold & silver inquiry 3% Cookie inquiry]	*When they said the bigger rocks had less surface area, so it didn't have as much of a reaction and the smaller ones had a great reaction because there was more surface area.* *The part with the explosions because they showed using big and small rocks and how that made a difference.* *The glass part when they were talking about how silver makes yellow and the gold makes the red. They mixed a bunch of chemicals together and nanosized the gold.* *In the very beginning, the cookie experiment thing, when they were making the cookies and it was easier to use up all of the sugar with the little cookies.*
Use of models to support content explanations	23% [17% Dinner plate changes to cheeseburger 3% Changes in sugar size 3% Blocks]	*How the big plate turns into the size of a mini hamburger.* *When Eric turned a plate into a cheeseburger.* *When he got the sugar cube and crushed it.* *The part with building blocks. There was one big block and the small blocks.*
Host explains directly to audience	7%	*The tablets, when he crushed the tablet, it made it bubble up more because there were so many pieces. I think that really made sense.*
Challenge question about propelling rockets?	10%	*The end, probably, the rocket thing, where it talked about the particles of aluminum.*
Category not clear	13%	*Not to do it by yourself but to do it with a grownup.*

Understanding Surface Area

Two-thirds of fifth graders said they had heard of the phrase "surface area" before viewing *Small is Different*, but only 30% of the sample could provide an acceptable definition. Significantly more children in the post-viewing interview could explain "surface area." Viewers identified two presentation formats as helping them the most: the "models" and the "kids' hands-on activities."

Before viewing *DFTV Nano: Small is Different*, the children were asked: *"Have you ever heard of the phrase "surface area"? Give me your best guess about what the phrase surface area means?"* After viewing, they were similarly asked: *"What does the phrase 'surface area" mean?"* Before viewing, two-thirds (63%) of fifth grade participants said they had heard of the phrase "surface area," and 30% of the children could give a reasonably correct definition of surface area. After viewing, significantly more (60%) children could describe surface area[27] (see Table 19). Viewing the program significantly improved the fifth graders' ability to verbalize an understanding that surface area refers to the total area of the exterior of a solid or 3D object. The remainder of the sample either referred to the top surface of an object (43% Pre, 3% Post), or referred to space occupied by an object or objects (0% Pre; 13% Post) or could not provide a relevant answer (27% Pre; 23% Post).

Table 19. Understanding the Phrase "Surface Area" (N = 30)

Category of Response	% Pre	Examples of pre answers	% Post	Examples of post answers
Reference to total area of the exterior of a 3D object	30%	*Surface area within mathematical terms means the exterior of an object – how large the exterior is.* *Like how much surface there is on a 3D object.* *We learned about it in school. It is the area of a 3 dimensional figure.*	60%	*It means the area around an object.* *The phrase 'surface area' means the space of the outside of a thing, the area outside the surface of a thing, like of a box.* *Surface area means the area around something, like with an object, it would be the area AROUND an object.*
Reference to space occupied	0%	-	13%	*How much space something can cover, like a rock can't cover as much space unless it is broken down and then it can spread out and cover more space.* *It means like how much space it takes up.*
Reference to the top of a object	43%	*The top of an object* *It means that it's like the top of something* *The top*	3%	*The phase surface area means probably around the top.*
No understanding or repetition of the phrase	27%	*The area of a surface* *I can't remember. We learned about this last year. It might have something to do with their habitat probably. That is just a guess.* *Like when you go surfing?*	23%	*The area of a surface* *It said surface area a lot but it didn't really say exactly what it meant.* *It's the surface of something. I forget.*

[27] McNemar Test of Paired Proportions, $p = 0.006$.

After answering the post-viewing question about surface area, viewers were asked *"what particular part in the show helped you learn that?"* or a follow-up of "*what in the show helped you think about surface area that way?"* Responses were sorted into the four presentation formats of interest in this study. Table 20 presents the percent distribution of responses for the categories and examples of viewers' answers.

Table 20 shows that 43% of viewers recalled models and 40% described the hands-on activities as supporting their understanding of surface area. No one described segments where the onscreen kids met with adults who showed them something or where Eric gave explanations with antacids or sunscreen.

Of the 60% of fifth graders in Table 19 (on previous page) who could describe surface area correctly in their post-interview, half (50%) noted the hands-on activities and half (50%) noted the models as aiding their understanding.

Table 20. Presentation Formats That Help Viewers Learn About Surface Area (N = 30)

Presentation Format	% Post	Examples of answers
Use of models to support content explanations	43% [30% Blocks 10% Changes in sugar size 3% Marco Polo]	*The blocks, where the surface area was smaller and you could see a lot more dots, like four dots instead of just one.* *The sugar cube part.* *The cells part, when they were doing the marco polo.*
Onscreen kids doing hands-on activities	43% [20% Soda inquiry 20% Cookie inquiry 3% Gold & silver inquiry]	*When they made the exploding soda. The bigger rocks made different kinds of explosions than the smaller ones.* *I think the baking one, because I could really tell the big cookie had less surface area than the smaller ones.* *Probably the stained glass, because when they did the silver, they kept adding more stuff and they got darker colors.*
Category not clear	13%	*There was not a part. It was confusing.* *I forget the idea about the middle part but I remember it being helpful.*

Presentation Formats That Showed What Happens When Surface Area Increases a Lot

Viewers felt that two presentation formats helped them to understand what can happen when surface area increases a lot: "onscreen kids doing hands-on activities" and "models."

After viewing, researchers asked: "*Some parts of the show explained what can happen when surface area increases a lot. What part do you remember that explained this idea – what can happen when surface area increases a lot?*"

Most (43%) viewers noted the hands-on activities as the format that helped them to understand what can happen when surface area increases a lot (see Table 21). Another 23% recalled the sugar, blocks, and marco polo game models. A small portion (7%) of the sample suggested that what helped them was when the adults showed the onscreen kids something. The host's explanation that a plate might change into a hamburger was noted by one viewer (3%), and 10% of viewers mentioned Eric's challenge question about exploding aluminum nanoparticles.

Table 21. Presentation Formats That Help Viewers Learn About What Can Happen When Surface Area Increases a Lot (N = 30)

Presentation Format	% Post	*Examples of answers*
Onscreen kids doing hands-on activities	43% [23% Soda inquiry 17% Cookie inquiry 3% Gold & silver inquiry]	*Probably when I saw what the rocks and pebbles can do when the soda exploded. This helped me get an idea how surface area connected to nano science.* *With that explosion with soda, the rocks had a medium sized explosion and the sand had a bigger explosion.* *I think the cookies, and how one of them* [onscreen kids] *made the cookies really small, and one of them made a really really big one, cuz each different cookie had a different surface area. The big one had less surface area than all the small cookies put together.* *The gold. They were making red and then it dissolved.*
Use of models	23% [13% Sugar; 7% Blocks; 3% marco polo]	*Breaking down the sugar cubes. You can spread it and it can cover a lot of parts.* *The block of cubes. It showed a bigger cube with a big surface area, and then he took them apart and each block had a greater surface area.* *The part where they did the voices and the nano things responded to each other when something was at it.*
Onscreen kids meeting with adults who show them something	7% [3% Glassblowing; 3% Flour explosion]	*It was during the glass blowing when they went into the museum.* *I think it mentioned that flour could explode or something like that.*
Host explains directly to audience	3%	*The plate and the hamburger. He showed the plate could be equal to one hamburger or an army of hamburgers.*
Challenge question about propelling rockets	10%	*For the aluminum, if you nanosize it, there are more pieces than just that one sheet, and they can do more power.*
Don't recall	13%	*I don't remember that.*

Presentation Formats That Showed How Scientists Work at the Nanoscale

Two presentation formats topped the viewers' list for showing how scientists work at the nanoscale: "onscreen kids doing hands-on activities" when the kids worked with the scientist to make and look at gold and silver nanoparticles; and "models" when the scientists used the marco polo game to explain cell communication.

After viewing the program, viewers were asked*: "The show explained how scientists did research at the very small nanoscale. What part of the show helped you to understand something about how scientists work at the nanoscale?"* (see Table 22). Almost half (43%) of the viewers recalled the hands-on activity where the onscreen kids helps a scientist make colored nanoparticles and the scientist uses an SEM to view at the nanoscale, and 43% of the viewers noted the use of the marco polo model presented by the nanoparticle toxicity team to explain cell communication. Small portions of the audience suggested that they learned about how scientists work at the nanoscale from the host explaining directly (7%) about fizzy antacids and sunblock and seeing the onscreen kids meet with adults who showed them solar cells (3%).

Table 22. Presentation Formats That Help Viewers Learn About How Scientists Work at the Nanoscale (N = 30)

Presentation Format	% Post	*Examples of answers*
Onscreen kids doing hands-on activities	43% [43% Gold & silver inquiry]	*How when they put the glass into the, well the metal alloys into the machine, how they could see them through that super sized piece of machinery.* *When the scientist did the effects with all the glass, when you had reduced silver and gold, and you put it under intense pressure and heat, it could change color.* *When they did the experiment to show how they dyed glass, and it showed how if the pieces were smaller, the color would be different.*
Use of models	43% [43% Marco polo]	*Where they had the team that was learning about toxic things and how they did the research on things that were toxic. It was good how there was a team and how they found results from doing an analysis and using different kinds of tools to help them work with things that are so small.* *The part where the whole team was researching, and they used the marco polo part and explained how the nanos were reacting to each other.* *I don't really remember the basis of the part but kinda the marco polo thing when they can tell that the particles kinda communicated with each other.*
Host explains directly to audience	7% [3 % Sunblock; 3% Antacid	*When they were talking about all the scientists figuring out about the sunblock and how tiny it is, which makes it more powerful and effective.* *When they took two dissolving pills and they crushed two of them into fine powder, and at first it was a solid and then they nanosized it.*
Onscreen kids meeting with adults who show them something	3% [3% Solar cells]	*Didn't they put that nano stuff on the solar panels?*
Don't recall	3%	*I don't remember that.*

How Presentation Formats Support Learning

Viewers explained how different segments within the four presentation formats helped them learn something. With respect to the hands-on activity format, the important characteristics were showing the viewer critical visual information and clearly demonstrating procedures and results of the activities. Fun activities, activities they could perform themselves, or content that viewers could relate to were also important to viewers' perceptions of effective learning. The format where on-screen kids meet with adults who show them something was effective because viewers felt that the scientists' explanations were age-appropriate and clear and that scientists know more. Similar characteristics were deemed important in the hosts' direct explanations to the viewing audience: Eric showed things and his explanations were clear. Viewers felt that the format of using models was effective because they showed them the content, gave clear explanations and provided examples with which they could connect.

When asked to choose a segment that contributed the most to their learning, 43% chose from the hands-on activities, 40% from the models format, 10% from the host's format of explaining directly to viewers, and 7% from adults showing something to onscreen kids. According to viewers, the critical characteristics contributing to learning in these choices were clear explanations and showing something visually.

After eliminating models from the list of formats, 43% of viewers preferred the format of watching adults present information because the adults were professionals who had more information and more accurate information. The format of watching onscreen kids doing something themselves was identified by 40% as most helpful, because the kids showed viewers things and because viewers could relate to and identify with the onscreen kids and their activities. Almost one-fifth of viewers opted for Eric's presentations because the host explained things clearly.

The second half of the post-interview explored more specifically which of the examples within the four presentation formats viewers felt was the most effective in helping them learn and why. Interviewers introduced this section of the interview by saying: "*The show used a variety of television techniques to help you learn. We want to know what television techniques helped you learn and why you think they were effective in helping you learn."* For each of the four presentation formats, the interviewers showed photos of segments and asked viewers to choose which segment helped them to learn the best and why. See Table 2, pages 5-7, for thumbnail versions of the segment photos.

On-screen kids doing hands-on activities. The researchers showed photos of three examples within the "hands-on activities" format and asked: "*The kids onscreen sometimes did some hands-on activities like making sugar cookies, or exploding soda bottles, or making gold and silver nanoparticles. Here are three photos from segments where the kids did hands-on activities. Which of these segments do you think helped you to learn the best?* [and in reference to the child's choice] *How was this hands-on activity effective in helping you learn something?"*

The characteristic highlighted most frequently with respect to the hands-on activities format was that the segments showed the viewer critical information rather than just telling the viewer. Secondarily, the viewers felt the format clearly demonstrated the procedures and results of the activities, reinforcing the learning outcomes. A few children also felt the activities were fun, or that they could perform the activity themselves, or they made a personal connection to the content. The viewing group spread their choices across all three segments, as shown in the percentages below; however, no female viewers chose "making sugar cookies" as the segment that helped them learn the best.

- 47% chose "exploding soda bottles."
  - The attribute noted most frequently was that the segment showed the results visually:
    Because it was measured, and they had multiple pieces that they could experiment with so you saw the difference.
    When you put the rocks in, when you actually showed the viewer what would happen and how high it went. I guess that helped the most.
  - Viewers also felt the procedure demonstrated clearly the relationship between particle size and reactivity:
    How the different sizes made it go higher or lower. The bigger one made it go lower, and the nanosize made it go higher.
    You would have thought the big one would have gone higher, so it helped me learn that wasn't the case.
  - Children thought the segment was fun:
    It was cool how it exploded in the air. It was just pretty cool.
  - Children felt the activity was something they could do:
    It was an experiment I could see doing at home or school.
- 37% chose "making gold and silver nanoparticles."
  - The attribute noted most frequently was that the procedure demonstrated clearly the result:
    It was more informational where the other ones were more fun and games, but with this one the scientists were with them the whole time, and they were explaining what they were learning.
    The girls helped me by watching them do it. They helped me by explaining the different steps and showing me what each color makes.
  - Viewers also felt the segment showed the results through the color changes:.
    It shows that many different things that you don't think could change can change into different colors or different objects. Like how they also measured the particles and showed how they are different.
  - Children thought the segment was fun:
    It was fun and interesting, so it helped me learn the most about it.
- 17% chose "making sugar cookies."
  - The attribute noted most frequently was that the procedure demonstrated clearly the result:
    I noticed that she made one big cookie and the other girl made multiple cookies with the

same amount of dough and, like with the blocks, she broke it up into a lot of little pieces. She didn't have enough sugar because the surface area increased, and this one [pointing to big cookie] *the surface just stayed the same.*

Because it was very clear. You could fit all the sugar onto a bigger cookie that had less surface area, and this was really easy to understand.

- Viewers also felt the segment showed the results through the surface area differences:.
  They had one big one and a lot of small ones. They covered one big one, and with the small ones, they didn't have enough sugar because they have more surface area, so seeing that was more effective.
- Children connected to the content:
  Because I really like cookies, and it made an impression on me. Because I like cookies, I followed it.

On-screen kids meet with adults who show them something. The researchers showed photos of three examples within the "adults who show something" format and asked: "*Sometimes the onscreen kids met with adults who showed them something, for example, they watched the flour explosion display, the electrical energy of different solar cells, and the making of glass. Here are three photos from segments where adults showed the kids something. Which of these segments do you think helped you to learn the best?* [and in reference to the child's choice] *In the segment you chose, the onscreen kids got information from an adult. How was that effective in helping you learn something?*

With respect to which segment helped learning the best, the viewing sample split their votes between the three segments; however, no female viewers chose the "flour explosion display." **Viewers reported that the format where "adults show onscreen kids something" was effective because the scientists' explanations were clear and the scientists know more.**

- ✶ 57% chose "the electrical energy of different solar cells."
  - Viewers most frequently noted that the scientist's explanations were effective because they were clear and scientists know more:
    It explained the most to me about the nanoparticles. It helps because the adults were able to explain everything they knew about what the kids wanted to learn better than the kids doing their own research.
    They explained it like a whole bunch, and that made sense.
    I think it was pretty effective because it showed someone who knew a lot about it. Little things and little energy can be made to have a lot of power.
    Adults usually know the right answer, and kids sometimes get mixed up.
  - A few noted that the procedure demonstrated the comparison:
    She showed them how two different things can make one do something faster. She at first showed the two little pieces of like the glass, and then she showed what they can do, how it could make a disc spin.
    Because it showed that the one with the nano wires I believe had more power than the other one.

- ✶ 30% chose "the making of glass."
  - The attribute noted most frequently as effective in helping them learn was that scientists' explanations were clear and scientists know more:
    Because it talked about the different particles and how it can change different colors. They know how to do this, and they have been working on it.
    The adults know more. If a kid was explaining it, you would probably get a little bit of some wrong information, but the adults have been doing it a lot longer, so they have better information.
    The adult explained things well about the glass and how crushing it affects things so much.
  - A few described how the segment showed them something:
    It showed how they made it and how they made it in the olden days, and how they put the minerals in and how sand could make glass and how colors can make different colors. That was really interesting because I would never know that.
    He was talking about how they made the glass, and they showed how they did it.
- ✶ 30% chose "the flour explosion display."
  - The attribute noted most frequently as effective in helping them learn was that scientist's explanations were age-appropriate and clear and scientists know more:
    The fact that the adult who knew about a certain area was more effective than someone who just told you out of memory.
    Explaining how when it has more surface area, it can be caught on fire easier. The adults explained it well, so it wasn't hard to figure out.
  - One viewer reported that the procedure demonstrated the comparison:
    Because you saw that how if you added oxygen or air to it, how it became less dense and more flammable, compared to being just stable.

Host explains directly to viewing audience. The researchers showed photos of two examples of the host format and asked: "*Sometimes Eric explains things to the viewing audience, for example, dissolving antacids or kinds of sunscreens. Here are two photos from segments where Eric did presentations. Which of these segments do you think helped you to learn the best?* [and in reference to the child's choice] *How was this explanation by Eric effective in helping you learn something?"* [28]

Eric's presentations were effective because he showed the viewers things and because his explanations were clear. With respect to which segment helped learning the best, the viewers overwhelmingly chose the antacid segment over the sunscreen segment.

- ✶ 87% chose "antacids" segment.
  - Viewers most frequently noted that Eric's segment showed visually that size of particles related to the fizziness of the antacid:
    He crushed up little like particles and showed how he can make a bigger amount, and

[28] The aluminum as rocket fuel challenge question was presented in three segments, and in developing the procedure, it was decided not to include the challenge in the category of the "host explaining directly to the viewing audience;" thus, an image from the challenge question was not among the examples respondents saw in the second half of the interview.

that was easy to see. He did it right there. It was really more how he showed it than so much what he said.

Because it gave a clear visual and showed you that it was more effective if it was crushed and had more surface area.

Because it showed that even though they seemed bigger that it didn't do as much as the ones crushed up because the crushed up had more surface area.

It shows it going up, and I think they did a replay during it, so it gave you a second chance to see it.

- Alternatively, an equal number of viewers felt that the host's segment was effective because his explanations were clear:
  The explanation was clearer in the antacids one.
  I didn't really get how the sunscreen would be clear with nanotechnology. He explained this one a bit more.
  Because he explained how when you have a smaller surface area how it was quicker to dissolve but when it was a bigger surface area, it took longer to dissolve. I was able to follow him because of the words he used. I liked how he said words like fizzy rather than something really scientific like fizzonic!
  The antacids because it showed how if it's crushed, it has a bigger surface area, it makes more fizz. He explained it pretty well, and most of the people watching will understand. It's not too technical with big hard words, and he has a cool shirt.

✶ 13% chose the "sunscreen" segment.
- One viewer noted that Eric's explanation was clear:
  I got what he was saying.
- One viewer felt the segment was effective because Eric showed something:
  I didn't know that sunscreen was originally white. Seeing it be white, so it was effective in teaching you something.
- The two remaining viewers could not articulate why they chose this segment as most effective in helping them learn.

Use of models to support content explanations. The researchers showed photos of four examples of the model format and asked: "*Sometimes segments used models to help you learn, for example, sugar cubes and blocks were used to model changes in surface area, the change of a dinner plate to a cheeseburger modeled how strange stuff happens at the nanoscale, and the marco polo game was used to model how cells talk to each other. Here are four photos from segments where models were used. Which of these segments do you think helped you to learn the best?* [and in reference to the child's choice] *How was this model effective in helping you learn something?'*

The models with blocks and sugar were most effective in helping the viewers learn. **Characteristics that viewers identified as important were showing them something visual, clear verbal explanations, and using examples they could connect to.**

✶ 47% chose the "blocks" model.
- Most viewers felt the blocks model most effectively showed them what surface area means:

It showed the dots on them, so then you could compare the dots, and I thought that was more effective.

They showed them all groups together, and they had a certain amount of surface area, and then they took it apart, and you could see that there was more.

Because it was completely physical. They actually showed counting them, and I think that helped.

- Several viewers chose the blocks model because the explanations were clear:
  I thought it was the clearest model. I didn't think the plate made that much sense.
  It wasn't as confusing. I got it more – like 27 cubes and 6 sides and you multiply that and there is 162.

- Children could connect to this example:
  Blocks are easy to imagine people doing things with because we play with them as kids.

✶ 30% chose the "sugar" model.
- Most viewers felt the sugar model showed more:
  It shows them breaking them down, and it shows you it could cover a pizza box, but if you break it down, you could cover several football fields.
  The smaller ones would fill up more space. There were a lot more small particles than in the big pieces, so just showing it, with pictures, it made it easy to understand.

- A few viewers chose the sugar model because the explanations were clear:
  He put a lot into explaining it.
  It helped to explain something that he was saying. It was what he was saying that helped me.

- Children could connect to this example:
  Comparing it to something in everyday life. This was the one to make the most sense.

✶ 17% chose the "marco polo" game model.
- Most viewers chose marco polo because the explanations were clear:
  Because it was clear that cells can make different, like if they were talking to each other, like if they were playing a game of marco polo, they could say something really quiet like 'polo' [whispers] *or different like 'spaghetti' or just normal 'polo.' I didn't know that cells could do that.*

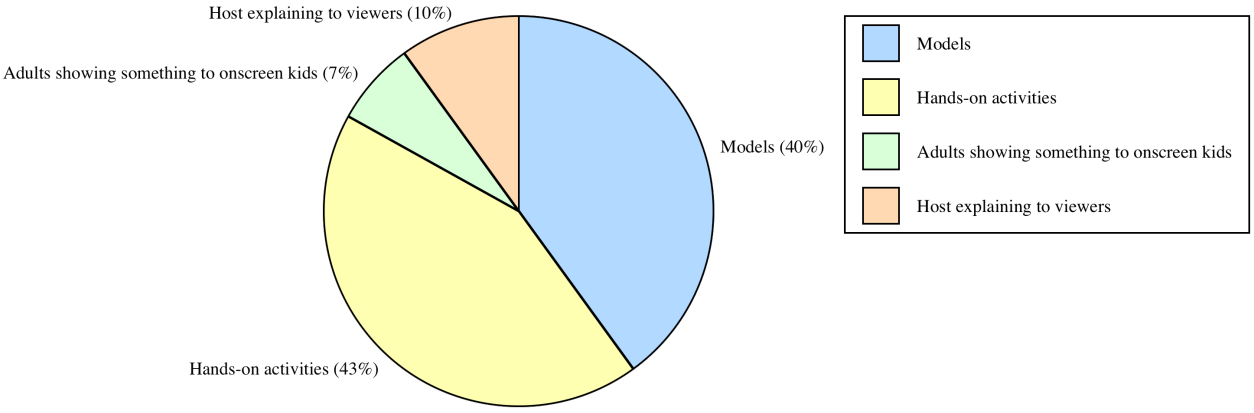
- A few viewers thought marco polo showed them how reactions are different:
  The marco polo because it showed how the reactions can be different because it can make sounds that are different.

- Children could connect to this example:
  They used marco polo, and we all kinda know that, so I thought it was a good example to use.

✶ 7% chose "dinner plate to cheeseburger" model, but viewers' thoughts on why the segment was effective did not fall into any of the categories that have been used for other segments.
Cause I never knew that a plate could make a full cheeseburger. I thought like when it said like break it into nano pieces, I never knew it would make a cheeseburger.
He was making it funny so you would learn more.

Which of four formats helped learning the most. After discussing each of the four formats as explained in previous pages, viewers picked from among their four chosen photos the one from which they thought they learned the most and explained again what it was about the segment and its television techniques that helped them learn. Figure 3 shows that viewers most frequently chose from the hands-on activities format (43%), including exploding soda bottles (30%), making gold and silver nanoparticles (10%) and making sugar cookies (10%). A similar proportion (40%) chose the models format, with most of the sample choosing the surface area models (blocks, 27%; sugar, 3%), and 10% choosing the marco polo game representing cell communication. A smaller portion (10%) of viewers picked the segment when the host, Eric, explained directly to viewers about different surface areas of whole and crushed antacids. Two children (7%) chose segments when the onscreen kids visited adults who showed them solar cells.

Figure 3. Formats which helped learning



With respect to three of the four format categories, the critical attribute contributing to learning was an age-appropriate clear explanation; for example:

- Hands-on activities:
  It was the most interesting experiment. Also it explained a lot about how nanoparticles could react differently.
  It was explained good so I would understand and could try it too.
- Models:
  I think the blocks – they really taught me all about surface areas. It explains a lot.
  Because it was more mathematic terms. The blocks were a little bit easier to understand.
- Adults showing something to onscreen kids:
  It kind of stuck in my brain. I don't really know why, maybe because it explained it a bit more, with what the scientist talked about.

The second most frequently noted attribute, related to three of the four formats, was showing something visually; for example:

- Hands-on activities:
  They showed us why the sand one got bigger than the rocks and pebbles.
  It clearly showed how the bigger rocks made smaller explosions and the smaller rocks made bigger explosions. It was easy to see how it was opposite, and it showed the steps so I was able to see it and believe it could happen.
- Models:
  Because the blocks showed you. They showed you all of it. They kind of showed you

counting the blocks and turning it over. That definitely helped. I felt like I was there. The other ones I didn't really get a good picture from.

- Host explaining to viewers:
  Because the others didn't really show the effects. The antacid one REALLY showed the effects.
  When Eric crushed them down, he showed that bigger isn't always better.

Which of three formats helped learning the most. After choosing a segment photo for one of the four formats, the "models" format was removed from the interview. Interviewers asked children to choose from the remaining three formats: *In this show, sometimes you watched the kids doing something themselves, sometimes adults presented information to kids, and sometimes the host Eric explained something to the viewer. Which of these techniques do you think had the most impact on your learning? Why?*

Figure 4 below indicates that 43% of viewers identified the format of watching adults present information as the most helpful for learning. Viewers felt that the **adults were professionals who had more information and more accurate information;** for example:

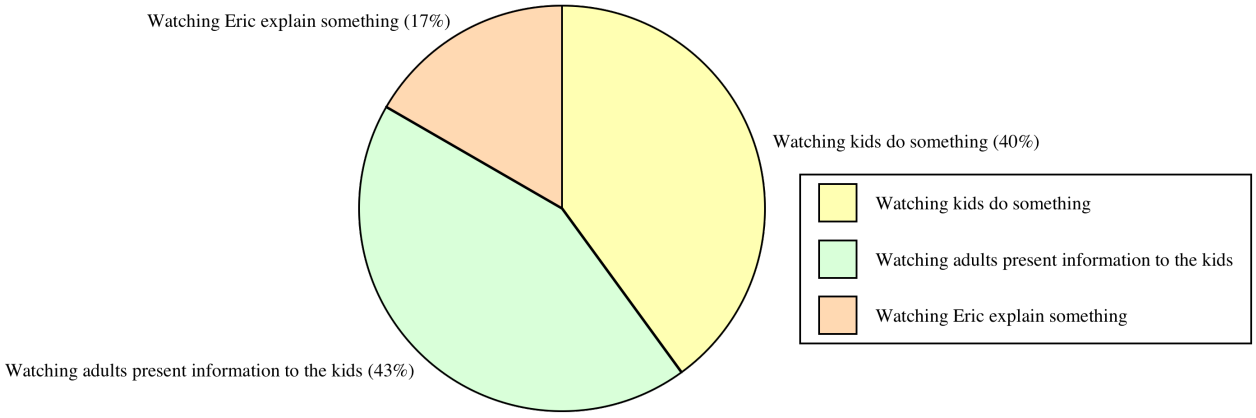
They seemed to know more about it. They were older, and you are still learning when you are a kid.

Because I kinda feel assured that it is the correct information, because kids aren't as smart as adults usually. These people are really smart because they have studied this stuff for like years, so it is kinda more assuring than just like kids.

These are people who have been working on this, and they know what has the different impacts.

Because they know about it more than the kids do. I like the experiments that the kids do, but if they did the experiments with adults too that would be a lot more fun to understand.

Figure 4. Formats which helped learning



Watching onscreen kids doing something themselves was chosen as the most helpful format for learning by 40% of the sample. The children reiterated that this format **showed them things**, but viewers also **could relate to and identify with the onscreen kids and their activities**; for example:

I think watching the kids, because I'm a kid too, so like if they can learn that much, then I know that I can learn that much.

Because I'm a kid too, and we can kinda connect because sometimes adults use really big words, and I can learn more with a kid talking to me than with an adult talking to me.
Because it is easy to relate to what they are like saying and stuff.
Because they're like our age, and they're doing things we could do.

Almost one-fifth of viewers (17%) chose the format of watching Eric explain something as the most helpful for their learning. Viewers felt that **Eric explained things clearly;** for example:

It was really easy to understand him. He was really funny and creative with a lot of things like the magnifying car.
Because he said a lot of informational stuff.
He showed what was happening and stuff, and he was clear and spoke slowly enough and explained things well.

Importance of Nanotechnology in the Future

All viewers concluded that nanotechnology will be very or somewhat important in the future. The children felt that nanotechnology has the potential to produce better sources of energy, that we can build or invent new things, or apply the technology in many different areas.

At the end of the interview, viewers were asked how important nanotechnology is going to be in the future and why they think nanotechnology will be important. Two-thirds (63%) felt that nano-technology will be "very" important, and 37% said it will be "somewhat" important. Viewers provided a range of reasons for why they felt nanotechnology will be important in the future, but most focused on energy uses:

- Nanotechnology has the potential to produce better sources of energy; for example:
  Because if you break down tin foil, into nanosize- what else could you break down- like plastic, or something really flammable- that could be even more effective. I think there is a lot of potential for it to do things that are powerful.
  Because it can be a resourceful source of energy to power different things like how tinfoil can be used with a rocket.
  Because if we can find different things that we can make nanosize, we can run different things like the rocketship so like we can do something else with it.
  I think it's going to be very important. Because it will also help like be eco-friendly to the earth and stuff, and also cause like it's gonna make solar energy, so it will help us a lot in the future.
  Because you could do more stuff with nanotechnology like the solar panels, because they help power things, and if you had the nanowires, it gave more power.
  Because it showed the solar panels and how they create energy and how they can be made cheaper in the future and conserve more energy. This is very important.
  Because they were talking about exploding and stuff too, so maybe it will be important during a war with like weapons. I don't know - it seems to be an important thing that we can learn more on. They talked about going green and things, like with the solar panels, which we kinda need to do because we are wasting a lot of stuff and using energy.
- With nanotechnology, we can build or invent new things; for example:
  Because we got to where we are right now from most of the reasons of all the new types of technology. I think nanotechnology is cool, it's efficient. I think we'll need it.
  The cheeseburger thing, maybe it would help make robots, the nano thing, like the cheeseburger, maybe it would help make robots.
  Because you can develop small space ships and that kind of thing, so the uses of it will be important.
  If we learn enough, we could turn something we don't need into fuel. Like we are having a food shortage in the world, and we have too much waste- we could just turn the waste into food.
- Nanotechnology can be used in so many different ways; for example:
  Because it could present alternative ways of using things and doing things.
  It's important because of all the products that can be made that will help our problems.
  There are many things nano can do for our homes and for how we live. We still are figuring out those ways.

DISCUSSION

The pre-post same-sample study implemented by Multimedia Research had two goals: first to assesss what fifth-grade viewers of a half-hour television program can learn about nanoscience and second to explore how television presentation formats and characteristics support viewers' understanding of nanoscience.

The programs were very successful in communicating their main messages of nanoscience, showing significant improvement in understanding after viewing.

Understanding the words "nano or nanotechnology." Although three-quarters of fifth graders said they had "heard of" the words "nano or nanotechnology" before viewing their *DFTV Nano* program, the preteens' understanding of the meaning of these words after viewing showed significant improvement over their understanding before viewing. After viewing the programs, 68% of the 60 fifth graders understood that "nano" refers to a very small size, and 32% understood that the term refers to a size too small to see with the naked eye. The latter group was most influenced by scientists' microscopic images within the presentation format of "onscreen kids meeting with an adult who shows them something."

After viewing the programs, 40% of the 60 fifth graders noted some property of matter in their description of "nano or nanotechnology." Although viewers' descriptions relative to properties of matter for both of these programs were not always scientifically accurate, they do show an expanded schema for nanotechnology beyond just a size definition. The format of "onscreen kids doing hands-on activities" in particular supported viewers' understanding. In *Small is Different,* the soda explosion inquiry demonstrated clearly that smaller-sized sand produces a higher soda explosion than larger-sized pebbles or rocks, and the gold and silver nanoparticle activity illustrated that nanosize particles can produce a different color than macrosize material. The "hands-on activities" in *Structure of Matter* in which the onscreen kids compared the strength and weight of wood, composite and carbon nanotube hockey sticks or compared the structure and color of butterfly wings also promoted the understanding that nanosizing can involve changes in properties of matter.

Understanding that structure inside can impact strength or color of an object. Viewing *Structure of Matter* significantly improved the fifth graders' ability to verbalize an understanding that the structure inside something can influence the strength or color of an object. In their answers about structure and strength, slightly more than half of the children referenced the structure of nanotubes or molecular structure and pointed to the "hands-on" hockey stick activity and the chicken wire "model" as facilitating their learning. In the chicken wire model, a flat-shape and a tube-shape of wire are compared with respect to holding up a bowling ball weight. In answers about structure and color, slightly less than half of the viewers made reference to light reflection as a function of structure. Most viewers suggested that the production format of "hands-on activity" comparing the structure and color of butterfly wings helped their understanding.

Understanding that some things change a lot when nanosized. In the post-viewing interview of *Small is Different*, there was significant improvement in the proportion of viewers who could explain the statement that "when some things are nanosized, they change a lot." Almost half of the viewers referred to the reactivity or color results of nanosizing and pointed to the "hands-on activities" of the soda explosion inquiry and gold and silver nanoparticle activity as aiding their understanding. The "models" format was also noted as communicating the idea that a lot of change can occur when things are nanosized, like a dinner plate changing to a cheeseburger.

Understanding surface area. Significantly more children in the post-viewing interview than in the pre-viewing interview could provide an acceptable definition of surface area as referring to the total area of the exterior of a solid or 3D object. Viewers of *Small is Different* identified two presentation formats as helping them the most: the "models" with blocks and with sugar, and the "kids' hands-on activities" with soda and with cookies.

In addition to the pre-post content questions summarized above, viewers also reported that their understanding of what can happen when surface area increases a lot was facilitated by the formats of "hands-on activities" and "models." These two formats in addition to the format of "onscreen kids meeting with adults who show them something" were pointed out by viewers as supporting their understanding of how scientists work at the nanoscale. Two presentation formats - "hands-on activities" and "host explains directly to the audience" - were perceived as helping recall of current or potential products using nanoscale structures.

Table 23 summarizes with checkmarks the presentation formats described by 20% or more of the viewers as helping their understanding or learning in *DFTV Nano*. This table suggests that two formats – "onscreen kids doing hands-on activities" and "models" are most effective.

Table 23. Presentation Formats That Viewers Perceived Helped Their Understanding

Presentation formats that helped understanding …	Onscreen kids doing hands-on activities	Use of models to support content explanations	Onscreen kids meeting with adults who show them something	Host explaining directly to audience
	✓= 20% or more who noted format as helping understanding			
… of the words "nano or nanotechnology"	✓		✓	
… that structure inside can impact strength of object	✓	✓		
… that structure inside can impact color of object outside	✓			
… that some things change a lot when nanosized	✓	✓		
… the phrase "surface area"	✓	✓		
…what happens when surface area increases a lot	✓	✓		
… how scientists work at the nanoscale	✓		✓	
… products using nano scale structures	✓			✓

Within each program, the four presentation formats were represented by two or more segments. Viewers chose which one of the segments within the four formats they felt was most effective in helping them learn the best and then explained why. Table 24 summarizes the characteristics that viewers attributed to each format across the segments and programs. A checkmark means that viewers described the characteristic in their open-ended interviews about the format.

Table 24. Characteristics That Viewers Describe As Helping Them Learn

Characteristics that help viewers learn	Onscreen kids doing hands-on activities	Use of models to support content explanations	Onscreen kids meeting with adults who show them something	Host explaining directly to audience
Clear demonstration of relationships, comparisons, procedures, results	✓	✓	✓	✓
Critical information is shown visually	✓	✓	✓	✓
Viewer connected to the content	✓	✓		✓
Explanations age-appropriate and clear		✓	✓	✓
Fun or funny	✓			✓
Viewer felt they could do activity	✓			
Viewers felt they could learn along with onscreen kids			✓	
Presenters [i.e., scientists] know more			✓	
Viewers could see how small nanoscale is			✓	

Characteristics that have proved to be effective in supporting learning of nanoscience in *DFTV Nano* also appear in other popular children's science programming. Shalom Fisch[29] summarized evidence for 14 "characteristics contributing to effective treatments of science and technology on television," 7 of which map onto the Table 24 characteristics of *DFTV Nano*, as follows:

Clear demonstration of relationships, comparisons, procedures, results	"balancing straightforward delivery of science content with a process of discovery"
Critical information is shown visually	"focusing on concrete, visual phenomena or devices, as opposed to abstract principles"
Viewer connected to the content	"topics that are inherently interesting to children and relevant to their lives"
Explanations were age-appropriate and clear	"presenting content via age-appropriate language and at levels of difficulty that are tailored to children's knowledge and developmental level"
Fun or funny	"enhancing appeal through age-appropriate humor"
Viewer felt they could do activity	"presenting experiments in ways that children can replicate at home"
Viewers felt they could learn along with onscreen kids	'including characters whom viewers see as competent and intelligent, and with whom they can identify"
Viewers could see how small nanoscale is	'focusing on concrete visual phenomena or devices"

[29] Fisch, S. (2004). *Children's learning from educational television:* Sesame Street *and beyond*. Mahwah, NJ: Lawrence Erlbaum Associates, p. 93.

In conclusion, this study demonstrates that the *DragonflyTV Nano* television programs can significantly expand pre-teens' understanding of nanoscience in terms of scale, properties, methodology and applications. The television presentation formats of showing "onscreen kids doing hands-on activity" and "models" were perceived by viewers as most effective in communicating the nanoscience messages, and the characteristics of *DFTV Nano*'s presentation formats that were identified as most helpful for learning include "clear demonstration of relationships, comparisons, procedures and results," "showing critical information visually," "connection to the content," and "clear age-appropriate explanations."