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Ken Burns Presents *The Gene: An Intimate History*

Genetics in the Classroom: Equipping Educators

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Executive Summary

In Spring 2020, a four-hour Ken Burns film based on Pulitzer Prize winning author Siddhartha Mukherjee's 2016 book, *The Gene: An Intimate History*, aired on public television. *The Gene* covered the medical, ethical, and political questions raised by genetic research and new gene therapies.

Improvements in scientists' understanding of genes and the rapid development of genetic technologies have made it increasingly critical for the public to understand the implications for daily living. With support from the National Institutes of Health and in partnership with the Public Genetics Education Project (pgEd), WETA developed educational resources for teachers and students learning about genetics. Since the start of the grant in 2019, Knology has been supporting the development of and evaluating the educational materials from the perspective of teachers and students.

In the first phase of the evaluation, Knology surveyed recent high-school graduates and conducted focus groups with teachers from middle school through high school. Both the focus groups and surveys assessed current understanding of genetic concepts, identified topics that were challenging for students and teachers, and where additional support was needed. Students generally struggled with vocabulary, understanding abstract genetics concepts, and making connections between concepts. The focus groups also asked questions about what resources teachers know and use as well as what materials would best support them. The analysis revealed varying levels of understanding of genetics concepts among teachers. Middle school teachers reported having a harder time teaching complex genetic concepts than high school teachers did.

In spring of 2020, Knology conducted the second and formative phase of the evaluation by gathering feedback from teachers on the curriculum materials that were being developed for use. We asked for feedback on their educational value and how they might incorporate them into their lesson plans. Generally, teachers liked the resources and described them as age-appropriate. They also appreciated the fact that the resources that were provided cover some new genetics technologies that are not yet included in textbooks. In interviews, teachers talked about some ways that they would modify resources to work for their specific age groups. They suggested things like creating separate vocabulary sheets for different grade levels or omitting some of the more complex details. Overall, teachers thought that the resources could be a valuable addition to their lesson plans and would be helpful for keeping students engaged.

In the final phase of the evaluation, we asked teachers about the effectiveness and impact of the resources on students as well as how easy it was to use the materials. Additionally, we asked teachers about how much time they typically spent teaching genetics and how they were using the resources that were provided. Due to the COVID-19 pandemic, we were only able to conduct interviews with two teachers. Additionally, we surveyed fewer teachers than initially planned. The feedback we got was mostly positive. In both the surveys and interviews, teachers said that they found the materials useful and that they connected well with their existing curriculum. Because most learning was remote in the last year, teachers

could give feedback on the feasibility of using the resources in virtual learning environments. Once again, the response was a positive one. Teachers reported that they found the material accessible and useful for teaching in both virtual and in-person settings. They also noted the resources improved their students' knowledge of genetics and were helpful for keeping students engaged in learning.



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Introduction

Ken Burns Presents The Gene: An Intimate History is a four-hour film based on Siddhartha Mukherjee's 2016 book of the same name. The film was released on PBS in Spring 2020. In conjunction with the film, WETA published a series of educational materials for use in classrooms. Development of these materials was done with funding from the National Institutes of Health (grant R25 OD020212-01A1).

Knology sought to evaluate the educational materials from the perspective of STEM teachers and students who may use the curriculum resources in their classrooms. The intent was to use the evaluation results to inform the final design of the resources.

The front-end evaluation (Barchas-Lichtenstein et al., 2019a) included two activities: focus groups with teachers, and a survey of recent high-school graduates. The questions that drove the front-end evaluation included:

- How does interest compare to perceived knowledge based on the core concepts outlined in the film content goals?
- What do prospective audiences already know and what do they not know?
- What persistent misconceptions exist that need to be addressed directly?
- What language and terminology do teachers and students best understand?

In Spring 2020, Knology gathered feedback on initial versions of the curriculum materials from teachers who would potentially use them in their classrooms (LaMarca et al., 2020). We had planned to recruit teachers to give three rounds of feedback on the materials. However, the COVID-19 pandemic meant that all US education was unexpectedly remote in Spring 2020, and we had to adapt our plans as a result. We could not ask teachers to test the materials in the classrooms so instead, we asked a group of teachers to look over the materials and talk about how they would use them.

This report briefly summarizes the findings from the two earlier reports. It also provides the results from a summative evaluation conducted in Spring 2021. The goals of this phase of the evaluation were to learn about students' interest in and engagement with the materials. Specifically, we wanted to assess how the educational materials could improve awareness and understanding of genetics topics among students. Due to ongoing challenges with COVID-19, we were only able to survey and interview a small sample of teachers. However, their feedback provides valuable insights into the effectiveness and value of the teaching resources.



Front-End Evaluation

Front-end evaluation for the project included two activities: focus groups with teachers and a survey of recent high-school graduates. These activities were conducted in the summer and early fall of 2019. The questions guiding the front-end evaluation activities were:

- How does interest compare to perceived knowledge based on the core concepts outlined in the film content goals?
- What do prospective audiences already know and what do they not know?
- What persistent misconceptions exist that need to be addressed directly?
- What language and terminology do teachers and students best understand?

Methods

Teacher Focus Groups

The evaluation team conducted four virtual focus groups with teachers in June, July, and September 2019. The focus groups aimed to understand how teachers incorporate genetics into their curriculum, challenges, resource needs, and sources of student misunderstanding about genetics. The four focus groups included 23 educators that teach different grades. Most participants were high school general biology teachers and AP biology teachers. Many teachers had experience teaching students in more than one grade level and often taught multiple classes. The focus group protocol consisted of five modules (see Barchas-Lichtenstein et al. 2019b for full details).

Two Knology researchers conducted all four focus groups. Each group was recorded, and one researcher took notes. One researcher did the primary analysis while the other gave feedback. We synthesized themes from the first two focus groups, and data from the remaining two were folded in. Also, after the first two focus groups, researchers categorized the responses into four groups: middle school, standard high school, advanced high school, and miscellaneous.

Youth Survey

We recruited approximately 150 young people, aged 18-25, to participate in a survey in September 2019. We gathered their perspectives on topics relating to the usefulness of learning genetics, as well as data on how they think about genetics – their conceptions and misconceptions about specific topics in the field identified by teachers in focus groups. Respondents had varying levels of exposure to genetics. A little over 20% of participants had never taken a course that covered genetics, and about 30% had little to no knowledge about genetics. The survey instrument consisted of three modules (see Barchas-Lichtenstein et al. 2019b for full details).

We tested whether the responses differed by topic and several nested factors, including age and self-reported knowledge level. We used multiple regression models to analyze ratings

on whether learning about genetics helped students think about six genetics topics, and how far topical ratings deviated from overall agreement across the six topics. We used logistic regression models to analyze the rates at which respondents fully endorsed correct conceptions or misconceptions of genetics, and the rates at which they acknowledged ignorance about the topic.

Results

Teaching Genetics

In focus groups, we asked teachers broadly about genetics topics that they currently include in their curriculum. Middle school teachers seem to focus on Mendelian genetics, with some information about cell division. They do not teach processes like protein synthesis or DNA replication in detail. High school introductory biology teachers said that they review Mendelian genetics in their classrooms and then move on to teaching about topics such as DNA structure. Teachers of advanced biology classes or electives related to genetics said they spend up to two-thirds of the school year on genetics topics and that they emphasize research opportunities in their classrooms.

Teachers said that they rely on online resources including educational websites for materials to use as supplements to their lesson plans. They cited resources such as science videos on YouTube as valuable teaching aids. Teachers generally liked shorter, modular activities for their classes because these offer more flexibility than whole-period lesson plans. Successful teaching strategies that were common across grades included growing plants and extracting student DNA. Others used things like manipulative models and visual exercises such as using doodle notes.

A common challenge that teachers mentioned was the difficulty of keeping up with new information and technologies. They also mentioned difficulties with answering questions that aren't covered in textbooks or where there isn't scientific consensus. Teachers also mentioned challenges with deciding what order to put topics in. Across grade levels, teachers were concerned about teaching some topics because of differences in students' backgrounds and perspectives. Examples were genetically modified foods, designer babies, and the use of CRISPR technology.

In terms of support needs, teachers across all levels wanted access to age and grade-level specific resources that aligned with topics in their lesson plans and state curricular requirements for what students should learn. They also wanted case studies and science journalism about recent findings that were written for their students' age level, as well as resources for teaching more advanced genetics concepts. Lastly, teachers stated that short, simple videos supplemented their lesson plans well. They wanted additional virtual resources such as interactive videos and online simulations to help students understand basic concepts such as mutations, as well as manipulative kits and visuals that help students understand higher level genetics concepts.

Learning Genetics

Common Challenges

In terms of vocabulary, students had three types of issues. According to teachers, students struggled with words that had both specialized and more common meanings. For example, many middle and high-school students associated the word *mutation* with having superpowers because of depictions in popular culture. Students also confused words with similar roots and spellings such as *chromosome* and *chromatic*, or words that described related concepts such as *diploid* and *haploid*. Finally, several teachers reported that students were confused about concepts like *gene therapy* and *epigenetics* that were hard to visualize.

Teachers also said that students struggled to understand some abstract genetics concepts, particularly those that went beyond a one-to-one mapping between genes and traits. For example, some students had a difficult time understanding how some traits are linked to genetics while others aren't, and how multiple genes can influence a single trait. Additionally, high school teachers mentioned challenges with helping students connect what they had learned previously in introductory genetics courses with what they were learning currently. This included topics that built on earlier lessons about topics such as Punnett squares, and differences within genetic processes such as between recessive and dominant genes.

When asked, students taking the survey endorsed the correct conceptions more often than the incorrect conceptions for about five out of six topics:

- Laboratory research
- Genetic basis of disease
- DNA
- Genetic determinism
- Patterns of inheritance
- Genetic technology

The topic of Laboratory research was the exception. On this topic, students endorsed the misconception far more often than the correct conception. This was also the topic that students were most likely to say they didn't know about.

Lastly, teachers observed that teaching genetics could lead to fruitful conversations about ethics in the classroom. However, they struggled with teaching these debates for two main reasons, which were related:

- Genetics was often the first context in which students encountered the concept of research ethics.
- Teachers could not always find clear and accessible materials that support diverse viewpoints about any given ethical question.

Common Opportunities

There were some topics that students understood quickly. For example, teachers said that students of all ages understood that children get half of their genes from each parent, and they could differentiate between sexual and asexual reproduction. Also, high school students had an easier time learning about genetic processes that have black and white answers or clear patterns such protein synthesis and DNA transcription.

Overall, teachers said that students were generally interested in genetics topics. This was confirmed by the results of the youth survey. In their responses, students agreed on the usefulness of learning genetics for particular topics. For example, they thought learning genetics was more valuable for thinking about genetically modified foods, health decisions, and different mental abilities. They found it less valuable for thinking about politics and stereotypes.



Materials Review

In the spring of 2020, Knology gathered teacher feedback on initial versions of the curriculum materials being developed for use in classrooms. The resources were released in conjunction with *Ken Burns Presents The Gene: An Intimate History*. We had originally planned to have teachers test the materials with students in their classes and provide three rounds of feedback. Due to COVID-19, we adapted this plan and instead asked teachers to look over the materials and discuss how they would use them.

Methods

Knology conducted 90-minute interviews with seven teachers to discuss how they would use the genetics learning resources provided. Teachers received the materials ahead of time and were asked to think about how they would use them in class. Two teachers reviewed each resource, and each teacher reviewed either four or five lessons and support materials.

Results

General Feedback

Teachers generally had positive things to say about the resources they received, and many said they thought that the resources would work for remote learning, even under the makeshift circumstances of the early pandemic. Teachers highlighted specific aspects of the materials that they liked, including animations and lessons that discussed newer technologies such as CRISPR and consumer genetic testing. They also liked materials that taught topics that their students could relate to such as ancestry testing and the effects of genetic mutations. Generally, teachers said that the materials provided were well-suited for the indicated ages.

Specific Feedback

Feedback in this subsection focused on specific lessons that fit into two main categories.

Treatments and Access

History, Access to Care, and Emerging Genetic-based Therapies: this lesson explored medical advances in genetics and invites students to consider the challenges of ensuring that the benefits are fairly and equitably shared. Teachers described the discussion questions and supporting articles for this lesson as really useful. They suggested expanding the vocabulary sheet to include additional terms.

Privacy Protection for Genetic Information: Meet GINA: this lesson focused on how scientists rely on people contributing their genetic information to research databases, and the laws and policies that protect this information. Teachers said that this lesson could be

used with any grade level with some adaptations. One teacher suggested that this would be a good place to include a lesson on ethics. They also suggested including a wrap up activity in the resources that would allow students debrief about their thoughts on GINA and make connections between specific concepts.

Genome Editing and CRISPR: this lesson described a specific advancement in genome technology for improving human health through altering DNA and explored some of the controversial issues associated with genetic modification. Teachers described the lesson as highly engaging, with one teacher stating that it was their favorite of all the lessons. They also said that the resources could be used for all grade levels but some of the supplemental materials might be better suited for older students. Teachers also said that the lesson could easily be embedded into their existing curriculum and could be used as a transition for teaching some of the history of science. They suggested improvements such as adding explanations for important terminology to the vocabulary sheet.

Identifying and Understanding Rare Genetic conditions: Meet Tess Bigelow: this lesson used the stories of two families to highlight advancements in genetic research and analysis. It looked at how these developments are helping children with a rare and undiagnosed condition. Teachers stated that they liked the lesson's focus on the experiences of real people and the way it exposed students to STEM research careers. However, they wanted more teaching materials included, and more details about the gene described in the lesson. One teacher suggested incorporating project-based activities into the lesson.

At Home Genetic Testing

Introduction to Genetics and Medicine: this lesson focused on some of the major health and medical reasons why people may choose to learn about their genetic makeup. In describing this lesson, teachers said that it provided a good baseline for understanding genetics. They stated that it should be the first lesson used in the classroom. The teachers also said that they liked the discussion topics included in the handout. One teacher suggested some specific ideas for remote activities to include with the lesson.

How Does Ancestry Testing Work: this lesson explored the science of genetic ancestry testing, and the impact of direct-to-consumer ancestry tests on people's understanding of their familial and cultural identity. Teachers said that this lesson was best suited as an introductory lesson for genetics. Teachers said that it would be interesting for their students since many have done ancestry testing at home. One teacher said that they looked forward to using it to supplement their evolution curriculum. Teachers also said that they liked the discussion questions and the activity that was provided with the lesson.

Direct-to-Consumer Testing in the Genomic Age: this lesson explored scientific developments in the field of personal genetics and direct-to-consumer genetic testing. Teachers generally said they liked the lesson materials and that it could be used to teach genetics in both middle and high school. They suggested providing additional background reading materials and expanding the vocabulary sheet to include more terms and definitions.

Ancestry Testing in the Genomic Age: this lesson explored genetic ancestry testing and how it adds to people's concepts of identity and history. Teachers said that they liked the

video that was included with the unit. They also liked the vocabulary sheet that was provided with the lesson and the four corners activity which they thought would work well as a remote activity. They suggested including materials that could be used to teach students about humanity's shared ancestry and foster conversations about race and how it is not genetic.

History of Eugenics

Genetics, History and the American Eugenics Movement: The lesson explored the history of eugenics in the United States and the dark past of genetics. Teachers said that they had difficulties with keeping the conversation focused on science without becoming political when teaching this unit. Teachers liked the vocabulary sheet and background information provided with the unit as well as the accompanying video. They also liked the discussion questions that were included with the lesson. Given the heavy nature of the material, teachers thought that this lesson was better suited for in-person learning.

Using Primary Sources to Examine the History of Eugenics: This lesson asked students to critically read, analyze, and interpret primary source documents that explore issues of race, gender, and class in the 20th century. Teachers said that they were hesitant to use this lesson in a science class. However, they thought that it was informative and connected history, social issues, and science. They suggested teaching this lesson in collaboration with a history or social studies teacher in order to properly discuss the different aspects of eugenics including its link to the Holocaust and implications.

Feedback on Animations

Teachers said that most of the videos could be used for students of wide range of ages. They said that the humor and style were appealing and simplified complex topics, and that the video series could be used for remote learning. The animation videos were:

- How Protein Synthesis Helps Pick your Nose
- What the Gene is That?
- Gene Whiz! It's a Boy!
- Good Genes Gone Bad
- Super Gene: Mutation Fact or Fiction?
- Gene Strike!



Summative Evaluation

Methods

Teacher Survey

Local PBS stations shared the survey with teachers who participated in their trainings about the resources for *The Gene*. The survey was intended to assess the effectiveness and impact of the resources on students as well as the feasibility and ease of use of the materials for teachers. We collected data between February and March 2021. We obtained seven complete responses. Due to the small number of responses, we only report descriptive statistics.

Participants

Only five teachers responded to questions about their teaching context: one taught middle school, one taught high school, two taught both middle and high school, and one taught undergraduate and graduate students. All five were public school teachers, and all five taught science. Two teachers said they taught general science while others used more specific descriptions such as biology, living environment, physics, and life science. One teacher also said that they taught social science and language arts.

Teacher Interviews

We conducted teacher interviews to help us learn how much time each teacher normally spent on teaching genetics, and to understand changes due to COVID-19. We also asked teachers to talk about how they used the teaching materials for *The Gene* and how specific materials contributed to student learning.

Knology originally hoped to conduct one virtual focus group with 6-8 teachers recruited through the survey. However, due to scheduling challenges, we were only able to complete individual interviews with two teachers. Two Knology researchers spoke with both teachers in April 2021. Each interview lasted 40 minutes and was recorded. One researcher reviewed the notes from each interview and identified consistent themes.

Participants

One of the two teachers interviewed was a middle school science teacher while the other was a high school teacher.

Results

Value of Training Sessions

In surveys, we asked teachers about the training they received (Table 1). Most teachers said that they found the training extremely useful and it helped them use the materials,

understand the materials, and get new ideas for teaching the materials in their classrooms. Teachers said that they were inspired by working with other teachers in breakout rooms during training and sharing strategies to use the resources and materials in their classrooms. Several teachers also said that the training was somewhat necessary to navigate the materials.

Table 1. Teachers' opinions about training materials.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The training helped me use the materials with my students.	0	0	0	3	1
I could have used the materials with no training.	0	2	1	1	0
The training gave me new ideas about how to use the materials.	0	0	0	2	2
The training helped me understand what materials are available.	0	0	0	2	2

Note. Numbers indicate how many teachers, of the seven who took the survey, selected each response.

Value of Specific Materials

We also asked teachers which lessons worked well for them and what worked well for their students. The lessons that were selected the most in both categories were **Gene Editing and CRISPR** and **Introduction to Genetics and Medicine**. This was followed by **Good Genes Gone Bad** (Table 2). On average, teachers used four lessons from the materials provided.

Table 2. Teachers' Assessment of Specific Lessons' Effectiveness

	Worked particularly well for students	Worked particularly well for teachers.
Gene Editing and CRISPR	3	3
Introduction to Genetics and Medicine	3	3
Good Genes Gone Bad	2	2
Ancestry and Identity in the Genomic Age	1	1
Gene Strike	1	1
Genetics, History, and the American Eugenics Movement	1	1
How Does Ancestry Testing Work?	1	1
Privacy Protections for Genetic Information: Meet GINA	1	1
Super Gene: Mutation Fact or Fiction	1	1
Using Primary Sources to Examine the History of Genetics	1	1
What the Gene is That?	1	1
Inclusion & Trust in Equitable Access to Precision Medicine	0	1

Note. Numbers indicate how many teachers, of the seven who took the survey, selected each response.

In interviews, both teachers also had specific comments about some of the lessons provided. For example, they liked that the lesson focused on the ethics of genetics included eugenics, and they liked the activities and resources that were provided along with lesson. One of the teachers, who teaches middle school, particularly liked the animation videos and said that they were great hooks for students.

According to these two teachers, their students responded well to stories that focused on an individual's experiences. They wanted to know more about the individuals in the lessons and find out about the progress of their diseases. Teachers also liked the videos that were provided with the lessons and thought that they presented information in novel and meaningful ways. They generally liked the length of the videos, which were quite short. One teacher mentioned that their honors middle school students could have benefitted from longer videos that went into more depth.

Teacher Self-Efficacy

We asked teachers about their experience with using the materials. Overall, teachers had good experiences with the materials. Almost all teachers either agreed or strongly agreed that the materials made it easier for them to teach genetics and that the materials improved their teaching. Almost all teachers said that they planned to use the materials again. Most teachers strongly agreed that the materials prepared them to answer students' questions and about half strongly agreed that the materials made it easier for them to teach about new advances (Table 3).

Table 3. Teacher Self-Efficacy with Materials

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I was able to use these materials successfully in my class(es).	0	0	0	3	3
These materials made it easier for me to teach genetics	0	0	0	3	3
These materials improved my teaching.	0	0	0	3	3
Using these materials saved time for me	0	0	0	1	5
These materials were easy to differentiate to meet all my students needs	0	0	1	3	2
These materials connected well with my required curriculum	0	0	0	2	4
I plan to use these materials again	0	0	0	0	6
These materials helped me generate productive resources with students	0	0	0	2	4
These materials prepared me to answer students' questions	0	0	0	1	5
These materials made it easier for me to teach about new advances	0	0	1	2	3

Note. Numbers indicate how many teachers, of the seven who took the survey, selected each response.

Student Learning & Impact

In surveys, we asked teachers what materials were most successful for students. Teachers specifically highlighted the videos noting that these were accessible, interesting, and engaging for students. They also thought the videos used the right level of vocabulary for the students. In their interviews, both teachers repeated these points. They described teaching materials and resources as accessible and great to use for both virtual and in person settings. They both found the resources to be the right level for their students and said they could easily customize the resources to their needs.

In terms of what was least successful, surveyed teachers said that their students responded better to color visuals as opposed to black and white videos & graphics. They also could have used more advanced versions of some of the activities which were too simple for older students. Lastly, teachers had some challenges with getting students to engage via online platforms.

We asked teachers about their students' learning outcomes. All teachers surveyed either agreed or strongly agreed that the materials improved their student's knowledge of genetics. Also, all teachers either agreed or strongly agreed that their students enjoyed using the materials and that they became more interested in genetics after completing the lessons (Table 4).

Table 4. Teachers' Assessment of Student Learning Outcomes.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
These materials improved my students' knowledge of genetics.	0	0	0	2	4
My students enjoyed using these materials	0	0	0	3	3
These materials increased my students' interest in genetics.	0	0	0	3	3
These materials were at an appropriate difficulty level for my students	0	0	0	3	3
These materials helped my students learn about new advances in genetics	0	0	0	3	3

Note. Numbers indicate how many teachers, of the seven who took the survey, selected each response.

Discussion & Recommendations

The overarching goal of this project was to create a series of resources that teachers could use in their classrooms to teach students about:

- Recent scientific advances, and
- Engage them in current social issues & debates

The response from teachers to the materials was extremely positive across the board. Both survey and interview responses from a small sample of teachers indicated that they found the materials useful and they that they saved time. They said that the resources connected well with their curriculum and helped them start good conversations in their classrooms. They specifically highlighted ways that the materials helped them talk about some more controversial and challenging topics in genetics with their students such as ‘designer babies’ and current political debates, as well as some of the darker aspects of genetics’ history. Some teachers highlighted the value of the resources to help them teach newer genetics topics that may not have been included or adequately covered in textbooks.

The COVID-19 pandemic afforded some teachers the opportunity to test the feasibility of using these resources in remote learning contexts. Their feedback was that these resources were valuable in remote learning, and they were able to adapt them to work on virtual platforms.

Recommendations

Teachers had several suggestions for ways to improve the existing lessons as well as additional resources that they thought would be valuable to include:

- One of the most common recommendations that we heard from teachers focused on tailoring the existing materials to work for students of different age levels. For example, creating *two vocabulary sheets for students at different grade levels*.
- Teachers thought that the resources would be valuable for their peers. One of their suggestions was to find ways to *share the lessons and materials with teachers more broadly* through an easily navigable website.
- Another suggestion was to combine the resources into a cohesive unit with suggestions for teachers on how to teach the lessons sequentially. One teacher suggested providing a *roadmap document* that lists out the lesson titles along with brief summaries of each to help with planning.
- For some lessons that were not directly about science, it may be beneficial to partner with other teachers. For example, when teaching the ethics of genetics, one teacher suggested partnering with a social science teacher for this lesson.
- Another suggestion was to include activities for students to do after watching the animation videos. One teacher suggested creating an activity that would assess what concepts students knew before watching the video and what they learned after.

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Behaviors

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