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Toward a New Model of Science Learning, Teaching, and Communication

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ABSTRACT

Sci-Toons is a new, experimental, teaching and learning approach that engages students in materials science research via interaction with experts, narrative, visual representations, iterative feedback and multimedia platforms. Based on a model (the Multimedia Theoretical Learning Framework) and multimedia design principles, Sci-Toon Creation Group (SCG) members, which include both science and non-science majors, work with faculty to produce video animations dealing with scientific topics. The creative process of producing scripts for two selected Sci-Toons videos dealing with materials science subjects (Graphene and Conductive Polymers) are discussed; initial and final versions of each are combined through use of Word Clouds.

The videos that are produced are distributed via the internet, providing instruction and information about materials sciences and other STEM topics. Demographic data about the types of individuals downloading these Sci-Toons are provided.

We conclude that Sci-Toons can be used in both formal and informal educational settings for science learning and teaching as well as in communicating materials science concepts to broad audiences including females and underrepresented minorities students.

INTRODUCTION

A report by the President's Council of Advisors on Science and Technology, *Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics* highlights the need to produce more STEM graduates [1]. If the number of STEM graduates is increased, there will be an increase in the pool of candidates from which the nation can draw for STEM-related positions. STEM education has also been linked to the development of science and technology innovation, maintenance of national security, and economic success: There is a continually high demand for people with STEM skills throughout the American economy [2]. Therefore, there is a need to develop comprehensive strategies to increase the number of students in the STEM pipeline so as to increase the number of STEM graduates who are in positions to solve current and emerging science and technology challenges, and occupy the increasingly STEM-relevant jobs of the future.

Comprehensive strategies to increase the number of students in the STEM pipeline and STEM graduates should include successful combinations of in-school and out-of-school STEM intervention programs [2,3] that engage students from all backgrounds. This is especially important for women and underrepresented minorities who now make up approximately 70% of all college undergraduates in the U.S. Several reports, including those from National Science Board and the U.S. Department of Education suggest that informal learning environments have the potential to strengthen science education on a national scale [4]. In this article, we compare and contrast the "perturbation/slight changes" in the methods used to produce two materials science videos: Graphene (https://www.youtube.com/watch?v=frgetR7qJec) and Conductive Polymers (https://www.youtube.com/watch?v=UjMbwS0LOkU) based on a novel approach dubbed Sci-Toons.

Sci-Toons focuses on the integration of narratives and animations, using multimedia technologies to produce products to promote science learning, teaching and communication for both viewers and participants in the production process. By November, 2015, Sci-Toons videos have been downloaded over 87,000 times; the materials science videos have been downloaded by viewers in at least 110 different countries. Data on the viewing impacts of Graphene and Conductive Polymers Sci-Toons videos, age and gender breakdowns of viewers of the videos, and demographics data of Sci-Toon Creation Group who developed the videos, as well as selected viewers' comments are presented.

THEORY

In order to deal with a viewer audience which is diverse with respect to learners' academic backgrounds and problem-solving styles, the Multimedia Theoretical Learning Framework was developed to identify an integrated approach that would be effective for both scientists, with their paradigmatic cognitive style, and for non-scientists, with their narrative (story telling) cognitive style. Implementation of this approach requires intensive interactions between members of the Sci-Toons Creation Group (SCG), who work together to produce Sci-Toon videos [5]. The SCG is composed of domain experts in the area being addressed, novices in the animation technique being employed, experts in the animation or visualization techniques being used, and novices in STEM domain content. Figure 1 shows the composition of a typical SCG.

Figure 1. Characteristics of Creator Groups for Sci-Toon projects

A key element of their creative process is iterative feedback. Those who are new learners (novices) with limited STEM domain content knowledge benefit from the feedback and interactions they have with the STEM domain experts. Conversely, the STEM domain content experts, who are novices to the visualization and animation techniques, learn from the animation domain experts. The Sci-Toons development process allows explanation of complicated scientific concepts through multimedia with clear and simple language, comprehensible to science learners.

An average Sci-Toon script goes through 3 to 5 iterative reviews. During each review, the SCG members work together to make sure the science concept is correct while keeping the language at the level that a general audience can understand. In other words, the SCG avoids jargon where possible, and clearly explains technical terms when they are used. This is different from other multimedia science videos which are written or produced by scientists or STEM experts who are often unaware of the target audience's lack of understanding of the language employed.

The SCG members producing the Graphene Sci-Toon included one African-American male, two Asian males, one Asian female, and one White female. The Conductive Polymers SCG members included one African-American male, one Asian male, one Asian female, and one White female. The process employed in the development and refinement of two Sci-Toons scripts (“Graphene” and “Conductive Polymers”) is discussed below.

The students who worked on the Conductive Polymer Sci-Toon had no prior knowledge of the content area. However, the STEM domain expert, a faculty member, had worked on several other Sci-Toon projects previously and possessed the necessary content knowledge. Two of the SCG members who worked on the Graphene Sci-Toon had previously worked on the Conductive Polymer Sci-Toon. The Graphene Sci-Toon also included two non-student domain experts. In the creation of the Graphene and Conductive Polymer videos, the SCG followed the three key steps for Sci-Toons video development: script development, storyboard production, and production of the Sci-Toon [5]. However, in making the Graphene Sci-Toon, the script and storyboard were developed concurrently while the script development process preceded storyboard production for the Conductive Polymer Sci-Toon.

Text visualization [6] was used to enable comparisons of initial and final versions of scripts, the underpinning of the video. Word clouds were produced through use of TagCrowd software [7] to provide insights into how the scripts evolved. To learn about the individuals downloading these videos, Google Analytics data were obtained. These data include the number of downloads and demographic characteristics of individuals downloading each of the Sci-Toons.

DISCUSSION

Figures 2 and 3 show the iterative nature of the scripts and the major changes that occurred from initial to final versions of the Conductive Polymer and Graphene scripts. Word clouds, a tool for qualitative data analyses, indicate the frequency of occurrence of words in a document by the size of the word. Words appearing more frequently are larger than words occurring less frequently. Common words, such as “and”, “an”, “a”, and “the” are ignored.

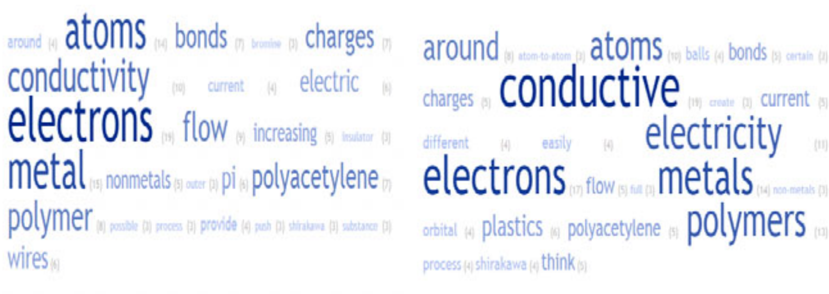

Figure 2. Visualization of the top 25 words of the initial Conductive Polymer script (left) and of the top 25 words of the final script (right)

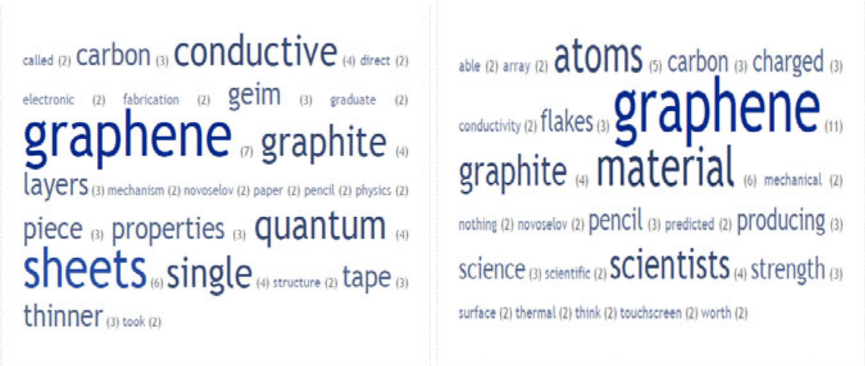

Figure 3. Visualization of the top 25 words of the initial Graphene script (left) and of the top 25 words of the final script (right)

The initial and final versions of the Conductive Polymers script showed few substantial changes as indicated by Figure 2. The word "nonmetal" was replaced by "plastics" and the frequency of use of "conductivity" was reduced. Overall, most of the initial concepts were retained. In comparison, the initial and final version of the Graphene script underwent substantial changes (Figure 3). Unnecessary jargon and technical terms such as "quantum" and "conductive" were used much less often; familiar terms such as "flakes", "materials", and "scientists" appeared much more frequently in the final script.

Viewer characteristics. As of November 3, 2015, the Graphene video has been viewed over 1,200 times while the Conductive Polymer video has been viewed over 13,300 times. There were 72 viewers of the Graphene video in India and 549 in the United States. The Conductive Polymers video was downloaded by about the same number of viewers in India (2,648) and the United States (2,711). The demographic characteristics of the viewers in these countries varied, as a function of the content as well as viewer gender and age.

In both India and the United States, substantially more viewers of both Sci-Toons were likely to be male. Males were also more likely to download the Conductive Polymers Sci-Toon than to download the Graphene video. (See Figure 4.)

Viewers of the videos tended to be younger in India than in the U.S. There were almost no viewers of either video in India who were 45 or over. Conversely nearly one-quarter (24%) of the male American viewers of the Graphene video and 6% of the female viewers of this video were at least 45 years old. About half of the viewers of these videos in India and at least one-third of the U.S. viewers were college-aged (18-24). (See Table 1.)

For the Graphene video viewers in these countries who were between 18-24, proportionately more females viewed the animations compared to their male counterparts. This was not characteristic of the other age categories, for which females were underrepresented. The Conductive Polymer video was viewed more by males in all age categories in India and United States.

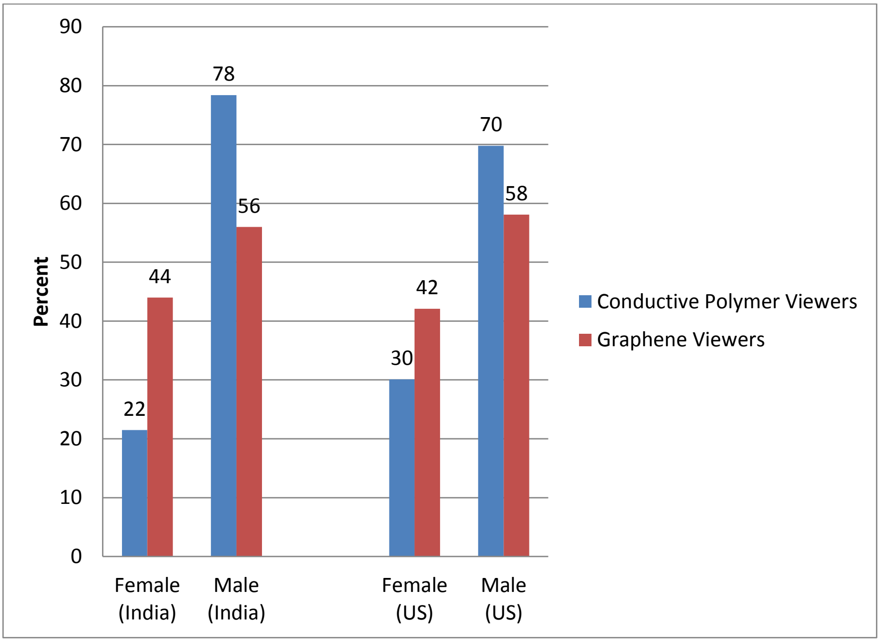

Figure 4. Indian and American Viewers of Sci-Toons Videos, by Gender

Table 1. Indian and American Viewers of Sci-Toons Videos, by Age and Gender

	Conductive Polymer Viewers				Graphene Viewers			
Age	India		U.S.		India		U.S.	
	Female	Male	Female	Male	Female	Male	Female	Male
13-17	2%	4%	1%	1%	4%	12%	1%	5%
18-24	13%	39%	15%	21%	28%	20%	24%	14%
25-34	5%	23%	7%	25%	8%	20%	6%	11%
35-44	1%	7%	3%	10%	4%	4%	4%	5%
45-54	1%	5%	3%	6%	0%	0%	1%	19%
over 55	0%	1%	1%	7%	0%	0%	5%	4%

Evidence of impacts on viewers can be inferred from the primarily positive comments they volunteered. These included: *"Excellent Video!" "Nice video with gorgeous visuals," "That's something really helpful for Project." "Great video. I did some more research on this topic and my curiosity is piqued" "Beautiful and explanatory." and "Nice work. Perfect presentation."*

CONCLUSIONS

The Sci-Toons approach was successfully used to integrate narratives and animations in the development of materials sciences educational videos. Through the process, the use of jargon and technical terms was reduced, to facilitate comprehension of the Sci-Toons by a diverse audience. This linguistic simplification was shown through word cloud comparisons of initial and final scripts. We also believe that the inclusion of individuals who are and who are not majoring in STEM as part of the Sci-Toon Creation Groups will greatly increase the likelihood of content understanding by a diverse audience.

Based on the number of downloads and the positive comments provided by viewers, these videos are almost certainly having an impact. Viewers tend to be male and mostly under 34 years old. The greatest proportion of viewers, in both India and the U.S., regardless of gender, were 18-24 year-olds.

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