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Work In Progress: The Development And Applied Use of Crash Course Engineering Videos For Formal And Informal Learning

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Abstract:

The growth of learning tools distributed through the internet has led to a dramatic increase in the number of freely available instructional tools applicable to both formal and informal learning systems. These include experimental module demonstrations, comics, and educational videos. Of particular note are the videos produced by Crash Course, which have created 38 series of YouTube videos, each focusing on individual subjects such as chemistry, history, or theater. The videos utilize animation to help highlight applications and theory, and have accumulated over 1.10 billion views since the first series was launched.

Crash Course: Engineering was a video series developed by Crash Course in association with PBS Digital, covering all fields of engineering in 46 episodes of approximately 10 minutes each. Over the course of the series, the origin of each branch of engineering was discussed, followed by discussion of core concepts of conservation, thermodynamics, fluid dynamics, heat and mass transfer, materials, statics, safety and ethics. The series then described applications of the different engineering fields, including robotics, genetic engineering, and signal processing, as well as specific extensions of core engineering fields, such as transportation and geotechnical engineering. The series concluded with an explanation of engineering design, careers in engineering, and the future problems to be solved.

The authors of this paper were part of the collaboration in the development and production of this series, serving as the engineering consultant who produced the syllabus to guide all written content for the series, and as the series' producer, respectively. Between the authors, all writing, filming, animation, and final editing was overseen and directed to ensure proper technical content and a greater degree of accessibility.

With this series having potential use in both high school and undergraduate classes, some of the engineering videos have been integrated into use in curricula as supplemental learning tools. This work will discuss the videos' audience, some current efforts towards analysis with both formal and informal learning, and future approaches.

Background

Videos have been utilized in education for decades, both in formal and informal learning environments.[1] YouTube in particular has been in use for more than a decade in college and high school classes, either for dissemination of the instructor's teaching or as a supplemental learning tool.[2,3] Instructors have the options of directly integrating the videos into the classroom as part of a lecture, or using them as a reference for students to review on their own.[4]

Videos have been shown to be effective learning tools given the potential combination of visual imagery, music, text, audio, and/or content.[5] Visual-spatial learners are particularly likely to benefit from video, as they would from photographs or other artistic mediums.[6] Videos have been effectively utilized in a broad range of subjects, including math[6], language,[3] literature,[7] and many other fields.

Videos can be used in several effective ways by instructors, including having students make their own videos; with respect to pre-made videos designed as supplemental educational tools, one useful approach is to have the videos assigned for review and critique.[8] Watching the video can thus reinforce concepts already learned in the class while stimulating confidence in the subject matter, and lead to further discussion in active learning opportunities. Student understanding of the content presented in the video can then be evaluated through the depth of the discussion or through exam questions to determine the effectiveness of the video.

Videos can also be used in more informal learning, such as through independent learning or tutoring groups.[9] The availability of YouTube and breadth of content on its platform makes it a particularly common tool for such learning to develop, with the popularity of certain videos and creators helping to drive more interactivity with those videos.[10] Learners may seek out additional educational content on their own to clarify their understanding, and well-crafted and interesting videos can serve to fulfill that supplemental learning.[11] Learners may additionally gain from the freedom provided to them, in that they are able to form parts of their own curriculum based on the videos they watch.[12] However, it can be difficult to assess informal learning from freely provided videos like those posted on YouTube without a supporting site or means of surveying the viewers; without the means of evaluating understanding, analysis of the videos is left to evaluating the viewership data and duration of interaction with the content.

The tradition of videos as educational tools, combined with the availability to make the videos available and readily disseminated through the YouTube platform, led to Crash Course. Crash Course is an educational company associated with PBS Digital that makes series of YouTube videos discussing courses generally covered in high school education. Crash Course was developed as part of YouTube's channel initiative in 2011, with funding being supplied to produce fun, educational videos that would be interesting and freely available to students and educators. The objective of Crash Course falls in line with some of the approaches from previous studies, in that the series are meant to be supplemental to but not supplant traditional education.[13] Each series is approximately 46 episodes long with each video around 10 minutes each, presented by a host and supported by animated scenes and equations as appropriate. These animations help to visualize the concepts, present a story, and in general help to make the entire video more entertaining.

Each series has a broad number of individuals working on it. Several producers help to ensure the series develops on time and meets the educational and entertainment standards expected by Crash Course. The host is often someone with understanding in the subject matter who presents the material with confidence and approachability. Writers develop the script for each episode, and a team of animators develop the unique visualization. Finally, a consultant develops the 'syllabus' for each series, effectively the structural outline for the entire series as well as the educational material that will go into each episode. Episodes are published weekly while each series is running. Each episode is released to YouTube, where the channel has over 10 million subscribers, and promoted through social media.

Crash Course: Engineering was the 33rd series produced. The series was released weekly from May 2018 through May 2019, and as of January 2020 has over 5.27 million total views for its 46 main episodes and one preview episode. The two authors of this paper served as the engineering consultant and producer for the series.

Crash Course: Engineering was thus a project launched from an established approach and focus. Many other educators and researchers have created videos for use in engineering education before, such as depicting communications in electrical engineering through simulation.[14] Studies have shown engineering education videos to be effective in different ways depending on their usage, such as reducing the time needed for face-to-face tutoring.[15] These videos have frequently focused on individual engineering majors or topics within individual engineering courses, however, and Crash Course: Engineering was developed to cover the overall field of engineering. Further, Crash Course: Engineering was effectively an extension of the project into the next field to cover, after having previously covered other subjects like chemistry, ecology, and literature; the best practices utilized in producing these engineering videos were thus based on previous efforts within Crash Course, and not based on work conducted by other researchers. The previous studies, on the other hand, will be most impactful moving forward in guiding future analyses of Crash Course: Engineering videos in formal and informal learning environments, by means of showcasing how videos can best be integrated into classrooms or tutoring.

Work-to-date with the Crash Course: Engineering videos has primarily focused on the production and release of the videos, given the length of time needed for development and distribution. Current and future work is and will focus on the impact of the series on students and learners in formal and informal learning environments, in consideration of previous results of similar YouTube educational videos.

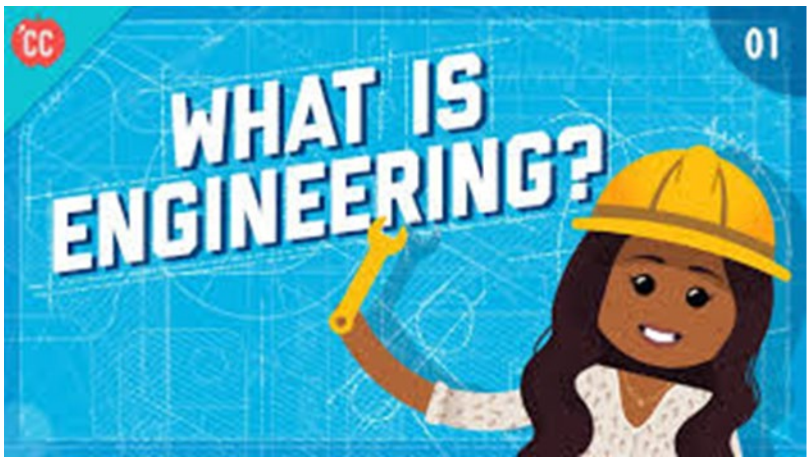

Figure 1. Title screen of the first episode.

Scope

Crash Course: Engineering was designed to cover all of engineering, with some episodes focusing directly on common concepts addressed or taught by several engineering branches, and more specific applications covered in separate episodes.[16-61] A key difficulty was meeting the initial proposal to cover 'Engineering' as a series topic. The breadth and depth of engineering meant any individual branch within engineering, such as chemical engineering, could easily have 46 episodes devoted to within that branch, or even within a single engineering course like thermodynamics. The direction to cover all of engineering meant that achieving a balance between all branches of engineering, with appropriate breadth and depth to cover key topics within each field, would take significant planning and effort before the series could even be filmed. Mapping out the series took ten months of research, which occurred while the series was being initially written, filmed, animated, produced, and released.

The series effectively broke down into several components. The first six episodes provided an overview of engineering (What Is Engineering?), including going into the history and main aspects of each specific branch of engineering (Civil Engineering, Mechanical Engineering, Electrical Engineering, Chemical Engineering, Biomedical and Industrial Engineering). These were followed by episodes #7-11, emphasizing conservation laws and thermodynamics (Laws of Conservation, Reversibility and Irreversibility, 0th and 1st Law, 2nd Law, Engines, Refrigerators, and Cycles).

The third component, episodes #12-17 focused on theory and application of momentum, heat, and mass transfer (Fluid Mechanics overview, Applied Fluid Mechanics, Heat Transfer overview, Applied Heat Transfer, Mass Transfer overview, Applied Mass Transfer). These were followed by seven episodes #18-24 discussing material characteristics and types (Properties, Metals and Ceramics, Polymers, Electric Power and Conductors, Semiconductors, Nanomaterials, Biomaterials). A few additional episodes, #25-28, covered a general range of other common theoretical areas (Process Control, Statics and Dynamics, Ethics, Safety).

The fifth component, #29-43, sought to provide an introduction to many areas of applied engineering, including areas of important current research as well as describing the subsets of major engineering branches (Environmental Engineering, Renewable Energy, Further Energy Resources, Batteries, Robots, Aerospace Engineering, Computer Engineering, Drug Discovery and Health, Biodevices, Genetic Engineering, Food Engineering, Geotechnical Engineering, Transportation Engineering, Communications and Signal Processing, Marine Engineering). Finally, the series ended with three episodes, #44-46, explaining the engineering design process, careers, and future directions (Engineering Design, How To Become An Engineer, The Future of Engineering).

The process for each episode began with the consultant developing the syllabus and assembling the important information to be covered within the episode. The team of writers would then develop the script, which would get edited and then approved by the consultant and producers. The host would record the episode without any visual animation, with final cuts approved by the producers and consultant, before the animation team would add in visuals. The final version would get reviewed a final time before being released.

Episodes were released on a weekly basis, and feedback through YouTube comments were not taken into account as the series was produced. The sole exception would be if an error was caught in the educational content, in which case a correction would be posted.

Analysis

This paper remains a work-in-progress as all the videos have been produced and released, but the impact of the videos is limited beyond what is known from viewership data. Evaluating the videos' impact in both formal and informal learning will require more direct analysis.

The analytics from YouTube allow for some feedback on the series. Because the series is freely released and not directly distributed into specific classrooms, the direct impact is difficult to determine on a broader scale. However, general viewership data does provide some insight into who is making use of the series and to what extent.

Viewers are characterized based on how their signed-in account information. This provides some insight into viewer gender and age. Watch time is the total number of hours each video was watched, views are the total number of times each video in the group was viewed, and view duration is watch time divided by views. (This is important as the YouTube algorithm prioritizes higher watch times, regardless of the actual length of the video.) View percentage instead calculates the percentage of the total video that was observed – so while a 2-hour-long video can result in a watch time of 10 minutes, the view percentage would recognize that only 8.3 percent of the video was watched.

In terms of gender, men represent 87.5 percent of the total views, and 90.3 percent of the total watch time. Men watch 45.1 percent of a video on average, while women watch 34.3 percent of a video on average. This is disappointing given the female host and diverse representation in the animated figures; however, this data may not be accurate, as it is reliant on evaluating the signed-in user's identity, and signing in is not required to be able to watch the video, nor have all signed-in users specified their gender. Thus, the percentage of views by men or women is strictly based on the signed-in users who have identified their gender in their account. It should be clarified as well that the number of views of users who are not signed in are not provided in YouTube's analytical data; in addition, the data is strictly binary, as the range gender identities are not accounted for in these calculations. Further analysis of these data would be helpful to understand their meaning, but the limitations in what is provided from the available information make it difficult to make any true determinations.

Viewership based on age is presented in Table 1. The majority of viewers being aged 18-34 suggests that the videos likely appeal to college students to help support their understanding, and potentially young professionals seeking to broaden their understanding. The 18-34 age range may also coincide with viewers who began watching Crash Course video series while in high school, dating back to when the channel first launched in 2012.

Table 1. Viewership data based on age.

Viewer age	Percentage of Total Views	Average percentage of each video viewed	Percentage of watch time
13-17	3.6	33.0	2.6
18-24	37.9	37.8	32.0
25-34	41.1	48.4	45.0
35-44	11.4	51.8	13.6
45-54	4.1	50.2	4.7
55-64	1.1	55.2	1.3
65+	0.8	47.9	0.9

With respect to location, the majority of viewers reside in English-speaking countries. Viewers have resided in 121 different countries and territories; of those, 68 countries had an average view duration of four minutes or more, and only 16 countries had an average view duration of five minutes or more. While it is possible that there is some relationship between percentage of viewers and country population, the large percentage of viewers from the United States is likely a result of other Crash Course video series being based around American high school courses and developing a direct fanbase from those students, such as U.S. History, U.S. Government, and English Literature.

Table 2. Viewership based on location.

Viewer location	Percentage of total watch time	Percentage of total views
United States	38.1	35.2
Canada	3.3	3.0
Great Britain	2.8	2.9
India	2.2	4.4
Australia	1.6	1.5

In analyzing which videos were watched the most, the overview episodes were clearly watched the most, with a sharp drop-off as the episodes transitioned into discussing conceptual theory. The average view duration of all the videos, not including the preview episode, was 4 minutes and 24 seconds. The video with the longest average view duration of 6 minutes and 35 seconds was Episode #10 entitled "Why We Can't Invent a Perfect Engine", which discussed entropy and the 2nd Law of Thermodynamics, suggesting resources for this concept were sought out the most. This was also the fourth most watched video overall, after the first three episodes in the series. Other episodes from later in the series with notable view duration and number of views were Episodes #30 and #31, discussing alternative and renewable energy resources, and Episode #32, discussing how to make better batteries.

Table 3. Summary of viewer data based on component grouping of the videos.

	Average watch time (hrs, rounded)	Average views (rounded to the nearest thousand)	Average view duration (hr:min:sec)
Preview (1 ep)	5,500	365,000	0:00:54
Eng Overview (6 eps)	22,400	302,000	0:04:31
Thermo (5 eps)	12,100	133,000	0:05:19
Transport (6 eps)	5,600	83,000	0:04:07
Materials (7 eps)	5,000	66,000	0:04:32
Ethics (4 eps)	3,400	50,000	0:04:09
Applied (15 eps)	5,100	70,000	0:04:19
Design (3 eps)	4,200	68,000	0:03:42

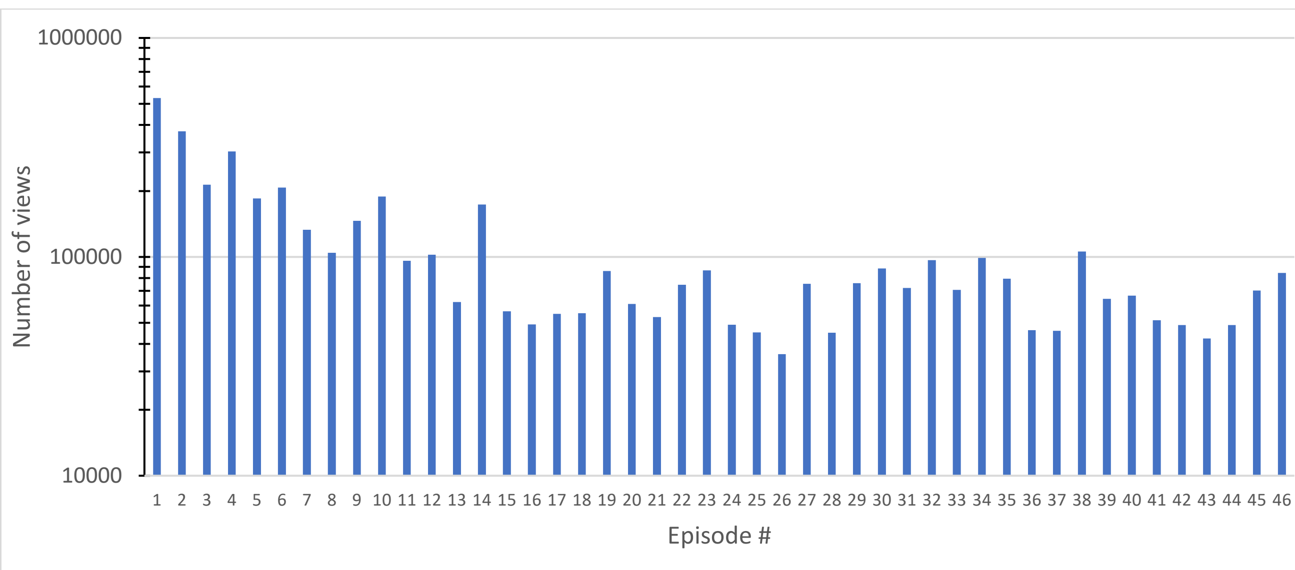

Figure 2. Number of views for each episode (not including preview episode), with views plotted on a logarithmic scale.

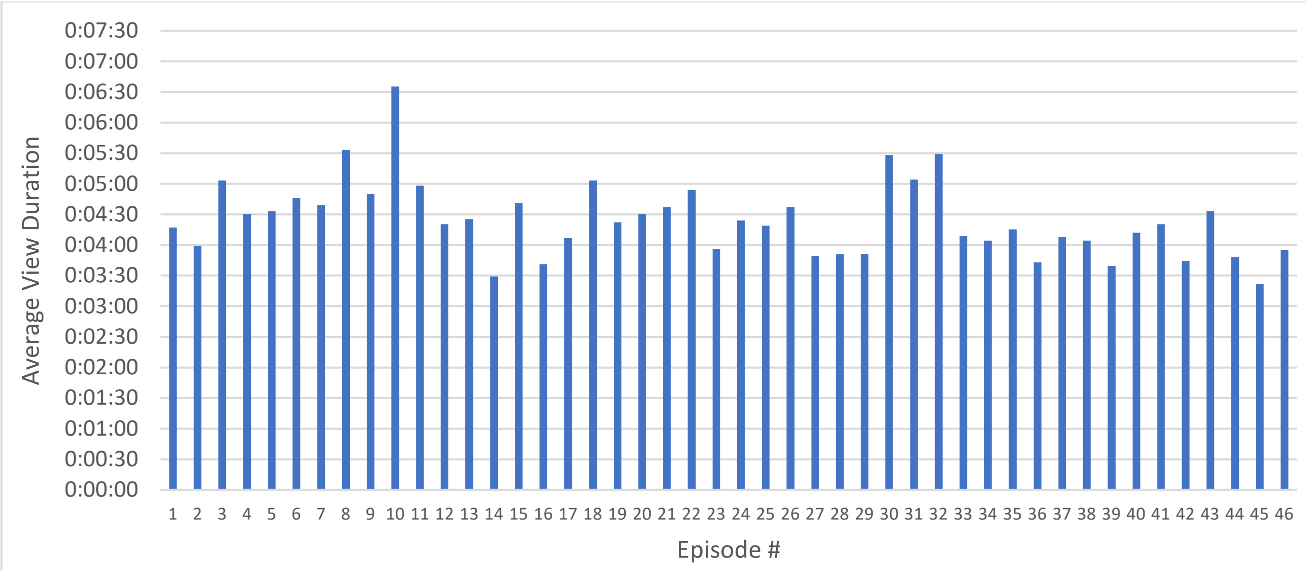

Figure 3. Average view duration (hr:min:sec) for each video.

It should be noted that YouTube data are limited to average values and do not provide a range of information to determine median or quartile analysis.

In general, viewers are lost at the end of each video when credits and wrap-up language begin, so the average view duration will always be lower than the full length of the video. This average view duration is further exacerbated by any viewer who stops watching right away because they decide they do not actually want to watch the content. If more complete data could be provided, it would be easier to determine when and how interest in each video was lost, given the different times that animations are introduced and utilized in the instruction; however, this information is not available from YouTube.

Further Work

To date, all analysis conducted with the videos have been in informal learning environments. The involvement of Crash Course in the direct educational use of the videos is limited beyond the actual creation of the videos, and depends on who the individual members on the production team are for each individual series. Given the consultant for this series was a current engineering professor, there is the opportunity for further study and analysis that has not always been possible with many of the previous series.

With all of the videos having been produced and released, they can now be integrated into formal and informal learning environments for which analysis of their impact can be determined. For example, several of the videos directly focus on subjects from thermodynamics courses, and could be used as supportive teaching tools in or outside the classroom to help students fully grasp the topics discussed. Depending on their use, these formal learning environments more fully analyze a students' understanding through quizzes, problem sets, and exams, and so the impact of the videos can be directly determined. These videos are now being used by different instructors for this purpose. Student feedback on the videos' perceived quality and content will also be collected through surveys, to help determine what aspects of the videos provided any benefit or detriment to student learning and interest. Effort will be made to go beyond college student classrooms and collaborate with high school instructors teaching related subject matter, as well.

Given the scope of the videos, a range of collaborators are needed to fully evaluate all the videos produced.

The videos can also be utilized by tutoring groups in informal learning environments. Student tutors in engineering at Northeastern University have been provided with links to these videos to help distribute them as appropriate, depending which undergraduate students seek assistance and on what topics. Obtaining feedback and tracking any students who utilize these videos are one possibility for further analysis, which need to be taken into account with the scope of the videos.

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