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The Effects of Student Learning When Subtitles are Added to Videos

George T. Taylor
Utah State University

THE EFFECTS OF STUDENT LEARNING WHEN SUBTITLES ARE ADDED TO VIDEOS

by

George T. Taylor

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Approved:

Edward M. Reeve, Ph.D. Major Professor	Trevor Robinson, Ph.D. Committee Member
Tyson Sorensen, Ph.D. Committee Member	

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ABSTRACT

The Effects of Student Learning when Subtitles are added to Videos

by

George T. Taylor, Master of Science

Utah State University, 2018

Major Professor: Dr. Edward M. Reeve, Ph.D.
Department: Applied Sciences, Technology, and Education

This project investigated whether adding subtitles to educational videos increases learning among middle school students. A convenience sample (N=387) of Technology and Engineering middle school students were separated into two groups during the third term of both the 2018 and 2019 school years, where one group of students viewed videos with subtitles and the other group viewed the identical videos without subtitles. After viewing the videos, students immediately took a multiple-choice test. The test scores were used to analyze the variance between the two different groups. The results reveal that students who viewed videos with subtitles had slightly lower scores than those who viewed the videos without subtitles. This project seems to indicate that viewing videos with subtitles does not improve learning more than viewing videos without subtitles among middle school students in a general class setting.

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CONTENTS

Page

CHAPTER I

INTRODUCTION

Students learn in a variety of different ways. It is widely accepted that teachers should try to adjust their teaching styles to meet the needs of the students. One method of teaching, which is becoming more prominent and popular in classrooms today, is the use of video instruction. It is important to determine whether the use of video in the classroom is productive to student's learning. Specific to this project is whether the use of subtitles in educational videos are more effective than videos without subtitles.

Purpose of the Project

The purpose of this project was to address whether the use of subtitles in educational videos improves student learning in classroom settings. The presentation of educational videos by general education teachers is increasing, and as such, it should be investigated as to whether this is beneficial to student's learning. As a Technology and Engineering teacher, I have noticed that many colleagues are showing educational videos more often to their students and this same trend is occurring in other academic departments as well. I have also increased the use of videos within my own classroom, specifically by having my students find and watch videos on YouTube for their research projects. As I researched and conducted a literature review about the use of videos with accompanying subtitles, I realized that their use might significantly increase student learning in a variety of ways. Some of these ways include better comprehension of subject matter, ability to recall details, and better performance on examination of knowledge.

To determine whether subtitles actually do make a difference, 387 of my College and Career Awareness middle school students took two sets of pre-tests about information in *How It's Made* educational videos. Students were separated into two groups. The first group of students viewed videos with subtitles, while the second group viewed the identical videos without subtitles. At the conclusion of the videos all of the students completed the multiple-choice test again. The multiple-choice test was used to determine if learning the content presented, was improved by the students who watched the videos with subtitles or without subtitles.

Problem Statement

Do subtitles in educational videos improve student learning among middle school Technology and Engineering students?

Assumptions

1. Students taking tests answered honestly and to the best of their ability.
2. The test administrator followed proper testing protocol.

Limitations

1. This project is limited to Technology and Engineering Education students attending a middle school in central Utah.
2. This project was administered to school age students that were required by law to be in school. It was not administered to students who have dropped out of school or otherwise absent.

3. The sample size of this project is limited, wherein students were conveniently taken from one Technology and Engineering teacher's classes at one middle school and the groups were not randomly assigned.

Definition of Key Terms

Video: A recording of a motion picture for playing through a television set or digital screen (Merriam-Webster, 2018).

Subtitles: Words that appear on the screen during a movie, video, or television show and that are translations of what the actors are saying (Merriam-Webster, 2018).

YouTube: The brand name of a website on which users can post, view, or share videos (Dictionary.com, 2018).

CHAPTER II

LITERATURE REVIEW

As the use of video continues to increase in the contemporary education classroom, questions arise as to its effectiveness in promoting student learning and achievement (Corporation for Public Broadcasting, 1997). Teachers who use video in their classrooms report that it reinforces reading comprehension, provides greater accommodation of diverse learning styles, increases student motivation and enthusiasm, and teacher effectiveness improves (CPB, 2004).

Howard Gardner's theory of multiple intelligences designates at least eight different ways of learning: linguistic, logical, spatial, musical, kinesthetic, interpersonal, intrapersonal and naturalistic. Several researchers from Harvard and Tufts University set out to prove that multiple intelligences exist (Gardner, 2006). Their goal was to identify how early individual differences are detected in children and what those differences were. This helped identify what cognitive competences children have and how to gear teaching and learning to those strengths. From their tests, it became obvious that there were several core capacities in each intelligence.

Many have criticized Gardner's theory, stating that it lacks empirical evidence, precise definitions and measurability (iraparenting.com, 2018). Despite this, there are implications of multiple types of learning and teachers may find increased learning among students by incorporating multiple types of instruction into their teaching practice. Specific to engineering and technology students (the main test subjects in this project), Felder & Silverman (1988) suggested that while there are many diverse ways in which

students learn, most engineering students fall into a few main categories. Teachers would do well to incorporate teaching methods that support these learning styles to improve student performance and creativity.

In a study done by Mettetal & Jordan (1997), one school implemented the multiple intelligences curriculum. It was found that students gained in self-confidence and teachers appreciated a wide variety of strengths. Most importantly, there was a positive impact on standardized test scores; they improved significantly over the 7-year test period reported in the study.

Silverman (2006) also suggested that there are three primary modalities through which people take in information: visual, auditory and tactile (VAT). There is conflicting data on whether teaching to modalities makes a difference in learning. Learning disabilities has emphasized the importance of determining whether dominant and weaker modalities exist and whether teaching to the dominant ones effects learning. Kampwirth and Bates (1980) found that teaching to preferred modalities did not make a significant difference in learning. Csapo & Hayen (2006) however, found that there are differences in modalities based on gender, race and geographic location. In addition, students may change their learning style as they progress through their education, which may be related to students adjusting to how a teacher teaches.

Instructional uses of video in the classroom may convey information simultaneously through "multiple entry points" (Gardner, 2006). Images, motion, sound, and text may benefit learners through both verbal and visual means. "When viewed together, each source provides additional complementary information," and the comprehension of this information takes place (Kozma, 1991). Video provides this as it

"promotes awareness of the interrelationship between picture, movement, sound, and captions" (Alex, 1999).

Various uses of video have been found successful as educational resources (Yang, et al, 2009). Mackey & Ho (2008), Mayer & Moreno (2002), and Rose (2003) all suggest that multimedia materials are more successful than paper-based instruction. Instructional Videos are reported being preferential by learners in their learning processes (Choi & Johnson, 2005; Choi & Johnson, 2007; Mackey & Ho, 2008). However, Danan (2004) pointed out that visual clues do not always support comprehension of actual spoken text. Danan referenced a study done by Baltova (1994) which found that groups given video and sound conditions did not perform better than groups given sound only conditions. It was suggested that other techniques such as captioning and subtitling may improve listening comprehension.

Hsu (1994) suggests that captions are perceived as a more effective learning method for watching educational videos. Multiple research studies have found that videos with subtitles and captions have helped students in language learning and listening (Chun & Plass, 1997; Danan, 1992). In a study done by Rokni and Ataee (2014), ESL students were divided into two groups; one watched videos with subtitles and the other group watched the same videos without. A post-test was given to the students after watching the videos. Results showed that the listening comprehension for the group with subtitles performed better than the group without. Winke et. al (2010) tested Arabic, Chinese, Spanish and Russian learners by showing them a combination of videos with and without subtitles. Results from t-tests indicated that captioning was generally more effective. Harji et. al (2010) conducted a test on students learning English as a foreign language and

whether their vocabulary scores were higher when students watched instructional videos with and without subtitles. The study showed that vocabulary learning was significantly higher for students who watched videos with subtitles.

Markham (1989) investigated the effects of subtitled TV upon the listening comprehension of beginner, intermediate and advanced learners of English. He used two subtitled videos on topics unknown to learners. Each of the groups viewed both videos with and without subtitles. He measured the participant's comprehension through multiple-choice questions based on the language of the video. When all three groups using the subtitles had better performance, he speculates that ESL (English as a Second Language) students may have improvements in their listening and reading comprehension simultaneously through video.

Danan (1992) also investigated the effects of subtitles in video and found that reverse subtitling may positively increase vocabulary recall. It was explained that students have a difficulty in recognizing words in different languages, especially if they are not familiar with the words and that listening and reading subtitles simultaneously may help students distinguish known from unknown words.

In another study, Garza (1991) compared Russian and ESL learners' recall of video segments with captions to video segments without captions. Garza selected five segments on particular genres of video between two and four minutes in length and used a multiple-choice test to measure students' comprehension of the video segments. Between these two groups, students who viewed the segments with captions had the highest scores.

In a study performed by Latifi et. al (2011), participants were Iranian learners subdivided into three groups: bimodal subtitles, standard subtitles, and no subtitles. Being tested was improvement of listening comprehension of the videos shown. Multiple choice tests and IELTS tests were given to the students. In summary, it was found that the group with subtitles performed better on the multiple-choice tests but the group without subtitles performed better than the other two groups on the IELTS test. This indicates that it is not quite clear yet, whether subtitles improve learning on all levels.

The studies reviewed above have shown some evidence that the use of subtitles while viewing video increases the learning achievement for students. The purpose of this project was to test whether videos with subtitles increase student learning for middle school students enrolled in Technology and Engineering courses.

CHAPTER III

METHODOLOGY

Research Design

To determine whether subtitles added to video improves learning among middle school students, this project used a quasi-experimental design and analyzed the results using descriptive statistics. A quasi-experimental design was used because the random assignment of the students was not possible.

Population

The population of this project was all (N=387) Technology and Engineering Education students (ages 12-13) enrolled in ten different 7th grade College and Career Awareness courses at a Middle School located in Central Utah during the third term of both the 2018 and 2019 school years.

Method

In this project, students from the third term of both the 2018 and 2019 school years were presented information from two television (TV) episodes about how pencils and sandpaper are made. These episodes are from a documentary TV series called "*How It's Made*" by the Discovery Channel. *How It's Made: Sandpaper* (episode 133) and *How It's Made: Pencils* (Episode 120) originally premiered between 2007-2008 on the Discovery Channel but students viewed digital copies viewed online via Amazon Video (Boyle & Hoss, 2008).

In this project, a content knowledge pre-test and post-test were used. All students were given the video content test as a pre-test before watching the videos.

Instrument

In this project, all students were shown technical videos on how pencils and sandpaper are made. To test their knowledge on the content of the videos, multiple-choice tests were developed by the instructor and administered to all students (See Appendix A & B). The tests were used as both pre-test and post-test instruments. Content knowledge measured in the test was developed based on information presented in the subtitle information of the videos. Test questions were developed word-for-word from the script of the videos (See Appendix C & D). The "distractors" for the test were developed by the instructor.

CHAPTER IV

FINDINGS

In this project, data were collected from students under two different settings. These settings are referred to as the Subtitled Video (SV) and Non-Subtitled Video (NSV). The output variables were the difference between the students' pre and post-test scores on the Video Content Test (VCT). Prior to viewing the SV, NSV, all students took the VCT as a pre-test. The students immediately took the VCT after watching the video. There were 387 observations in the data set. Results from this project indicated that the subtitles made little difference in helping improve test scores.

Data Analysis

During the 2018 school year, students (N=88) in the instructors first through third periods watched the *How It's Made: Pencils* with subtitles, and students (N=92) in the instructors fourth through sixth periods watched the same video without subtitles. Immediately after watching the videos, the students retook the video content test. The average test scores for these students are shown in Table 1 and Table 2, respectively.

Table 1.

2018 School Year Scores from Students Who Watched How It's Made: Pencils with Subtitles.

2018 Pencils	Pretest Scores	Videos With Subtitles	Posttest Scores	Change In Scores
Period 1	8.59	N=27	13.26	4.67
Period 2	9.5	N=30	13.96	4.46
Period 3	9.23	N=31	13.77	4.54

Table 2.

2018 School Year Scores from Students Who Watched How It's Made: Pencils without Subtitles.

2018 Pencils	Pretest Scores	Videos Without Subtitles	Posttest Scores	Change In Scores
Period 4	9.36	N=34	14.69	5.33
Period 5	10.15	N=26	14.73	4.58
Period 6	9.47	N=32	14.44	4.97

During the 2019 school year, students (*N*=80) in the instructors third through fourth periods watched the *How It's Made: Pencils* without subtitles and students (*N*=85) in the instructors fifth through sixth periods watched the same video with subtitles. Immediately after watching the videos, the students retook the video content test. The average test scores for these students are shown in Table 3 and Table 4, respectively.

Table 3.

2019 School Year Scores from Students Who Watched How It's Made: Pencils without Subtitles.

2019 Pencils	Pretest Scores	Videos Without Subtitles	Posttest Scores	Change In Scores
Period 3	9.93	N=38	16.37	6.44
Period 4	8.5	N=42	14.14	5.64

Table 4.

2019 School Year Scores from Students Who Watched How It's Made: Pencils with Subtitles.

2019 Pencils	Pretest Scores	Videos With Subtitles	Posttest Scores	Change In Scores
Period 5	8.9	N=42	14.19	5.29
Period 6	10	N=43	15.07	5.07

During the 2019 school year, students (*N*=82) in the instructor's second and fourth periods watched the *How It's Made: Sandpaper* with subtitles, and students (*N*=80) in the instructors fifth through sixth periods watched the same video without subtitles. Immediately after watching the videos, the students retook the video content test. The average test scores for these students are shown in Table 5 and Table 6, respectively.

Table 5.

2019 School Year Scores from Students Who Watched How It's Made: Sandpaper with Subtitles.

2019 Sandpaper	Pretest Scores	Videos With Subtitles	Posttest Scores	Change In Scores
Period 2	6.66	N=41	16.21	9.55
Period 4	7.22	N=41	16.1	8.88

Table 6.

2019 School Year Scores from Students Who Watched How It's Made: Sandpaper without Subtitles.

2019 Sandpaper	Pretest Scores	Videos Without Subtitles	Posttest Scores	Change In Scores
Period 5	5	N=39	15.62	10.62
Period 6	5.83	N=41	16.2	10.37

In each case, when comparing average student scores between the SV and the NSV, the NSV students saw the largest gains to their post-test scores. During 2018 and 2019, the average pre-test score on *How It's Made: Pencils* for all periods of NSV students (N=172) was 9.48 and the average post-test score was 14.87. On average, these students saw a 5.39 point increase in their score after instruction. These results are shown in Table 7 below.

Table 7.

Average Scores from All Students Who Watched How It's Made: Pencils without Subtitles during 2018 and 2019.

Pencils	Pretest Scores	Video Without Subtitles	Posttest Scores	Change In Scores
All Periods	9.48	N=172	14.87	5.39

During 2018 and 2019, the average pre-test score on *How It's Made: Pencils* for all periods of SV students (N=173) was 9.24 and the average post-test score was 14.05. On average, the students saw a 4.81 point increase in their score after instruction. These results are shown in Table 8 below.

Table 8.

Average Scores from All Students Who Watched How It's Made: Pencils with Subtitles during 2018 and 2019.

Pencils	Pretest Scores	Video with Subtitles	Posttest Scores	Change In Scores
All Periods	9.24	N=173	14.05	4.81

During 2019, the average pre-test score on *How It's Made: Sandpaper* for all periods of NSV students (*N*=80) was 5.42 and the average post-test score was 15.91. On average, the students saw a 10.49 point increase in their score after instruction. These results are shown in Table 9 below.

Table 9.

Average Scores from All Students Who Watched How It's Made: Sandpaper without Subtitles.

Sandpaper	Pretest Scores	Videos Without Subtitles	Posttest Scores	Change In Scores
All Periods	5.42	N=80	15.91	10.49

During 2019, the average pre-test score on *How It's Made: Sandpaper* for all periods of SV students (*N*= 82) was 6.94 and the average post-test score was 16.16. On average, these students saw a 9.22 point increase in their score after instruction. These results are shown in Table 10 below.

Table 10.

Average Scores from All Students Who Watched How It's Made: Sandpaper with Subtitles.

Sandpaper	Pretest Scores	Video With Subtitles	Posttest Scores	Change In Scores
All Periods	6.94	N=82	16.16	9.22

CHAPTER V

DISCUSSION AND CONCLUSIONS

The purpose of this project was to investigate if watching a video with subtitles improved student learning of the content presented in a technical video about the making of pencils and sandpaper. In this project, the same videos were shown to two different groups of middle school students. One group watched the video without subtitles and the second group watched the video with subtitles. To measure student learning, a pre-test and post-was used. The test scores from the tests were used to analyze the difference between the two groups and the results showed that on average, students who viewed the video with subtitles actually had lower scores on the test than those who viewed the video without subtitles.

The question asked in this project was: Do subtitles in educational videos improve student learning among middle school technology and engineering students? In this project, the results seem to indicate that the subtitles made little difference in helping improve test scores and that watching a technical video with subtitles negatively affects student learning for this population.

While the results of this project seem to indicate that watching videos with subtitles does not improve student learning among technology and engineering middle school students, there are many factors that could have influenced the findings in this project. All students who come to the classroom are unique and the variables associated with this uniqueness influence their learning. For example, below is a list of student characteristics that may impact student learning. These characteristics were not measured

in this project but should be considered in future research on this topic. These characteristics include:

- Gender, race, and/or ethnicity
- Socioeconomic status
- Individual Learning Plans
- English Language Learners
- Learning styles
- Reading level/Reading speed/Reading comprehension
- Personality/Attitudes
- Sleep
- Nutrition
- Physical Health
- Emotional Health
- Personal confidence
- Home life
- Single-parent versus two-parent family
- Values
- Motivation
- Voluntariness

In addition to the above student characteristics, the classroom and surrounding environment can influence student learning and should be considered in future research. Below is a list of some unknown variables to consider in relation to the school and classroom environment not addressed in this project:

- Routines and procedures
- Number of students
- Size of space
- Displays
- Disruptions
- Bell schedule, class duration, time of day
- Ventilation
- Smell
- Teacher style and personality
- Student diversity
- School location

Each of the variables above, if taken into consideration for this project may change the results. For future studies, I would recommend comparing test results from students with disabilities, students on Individualized Education Programs (IEPs), students that are English Language Learners and students with differing learning styles.

In this project, I speculate that student's fall into a mix of different groups and that students in these various groups are distracted by subtitles, while others have higher levels of learning because of them. For instance, if there are different learning styles among students, it could be possible that visual learners might be benefited by subtitles and on the other hand, they might hinder auditory learners. Similarly, it could be possible that they might also distract students who are learning English as a Second Language, especially those who are limited in their ability to read English.

Despite receiving results from this project that indicates that viewing videos with subtitles do not improve learning more than viewing videos without subtitles, it inspires further research questions that I intend to test in my classroom in the future. One that I have already begun to investigate is whether a "class lecture improves learning" more than viewing videos with, or without subtitles.

To test this idea, a third group of students was taken from the instructor's second and third periods during the 2019 school year, and rather than viewing videos with or without subtitles they had an "in-class lecture" which referenced the same information in the videos. This process was done for the two different videos, where students (N=34) in the instructors second period received the lecture on *How It's Made: Pencils* and the students (N=39) in the instructors third period received the lecture on *How It's made: Sandpaper.* Immediately after receiving the lectures, the students retook the video content test. The average pretest score from the students who had the lecture on *How It's Made: Pencils* was 8.73 and the average post-test score was 14.59. On average, the students saw a 5.86 point increase in their score after instruction. The average pretest score from the students who had the lecture on *How It's Made: Sandpaper* was 6.59 and the average post-test score was 18.34. On average, the students saw an 11.75 point increase in their score after instruction. These results indicate that the students who received an in-class lecture had higher scores than those who viewed a video with or without subtitles.

Although the subtitles did not seem to improve student learning, it is important to note that after students watched the video and retook the content test, their scores on average increased by 36%. In other words, this project seems to show that if students take a pre-video content test, watch a technical video or receive a classroom lecture, then

retake the identical content test, their content knowledge on average will increase by 36%. It is also important to note that when students were asked in a class survey whether subtitles would help students learn better, 77% said that they would. Also, after students had taken the test 66% of them expressed complaints that the subtitles were distracting to them as they watched the video. Another interesting observation was that students expressed excitement to retake the test after having watched the video a second time. It seemed that students were intrinsically motivated to see if they had an increase in their post-test scores.

By completing this project, I have learned that students can increase their content knowledge and greatly benefit by taking a pretest and then taking the same test a second time. I learned that important information may be gained from surveying students and that student perceptions of their own learning may be beneficial in how a teacher prepares and continues with their instruction.

Recommendations for future research:

For those interested in doing further research on the topic studied in this project, I would recommend that the following questions be investigated:

1. Do subtitles in educational videos improve student learning among students with disabilities more than students without?
2. Do subtitles in educational videos improve student learning among students who have free/reduced school lunch or fee waivers more than students who do not?
3. Do subtitles in educational videos improve student learning among students receiving Individualized Educational Programs more than students who do not?

4. Do subtitles in educational videos improve student learning among students learning English as a Second Language more than students who are not?
5. Do subtitles in educational videos improve student learning among students with some Learning Styles more than others?
6. Do subtitles in educational videos improve student learning among students with different personalities or learning preferences more than others?

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APPENDICES

Appendix A

Video Content Test for *How It's Made: Pencils*

1. Lead inside a pencil is not actually lead, it is mostly _____

   a. Graphite

   b. Clay

   c. Charcoal

   d. Wood

2. This German pencil factory uses _____from California

   a. Maple

   b. Oak

   c. Cedar

   d. Walnut

3. The wood is 0.2 inches thick and arrives pre-cut in _____of seven by two and a half inches

   a. Bundles

   b. Blocks

   c. Slats

   d. Stacks

4. One by one, the slats pass under a giant _____wheel

   a. Cutting

   b. Sliding

   c. Adhesive

   d. Lubricating

5. It carves grooves that will become the _____down the middle that holds the lead

   a. Line

   b. Slot

   c. Channel

   d. Hole

6. The next machine fills the grooves with _____, a special formulation that's slightly elastic

   a. Glue

   b. Rubber

   c. Plastic

   d. Oil

7. This cushions the lead so that it's less likely to _____

   a. Crack

   b. Bend

   c. Break

   d. Split

8. Every second slat moves onto another conveyor _____

   a. Wheel

   b. Platform

   c. Belt

   d. Table

9. The lead is made of a graphite and _____mixture baked in an oven at almost 1500 degrees Fahrenheit

   a. Carbon

   b. Charcoal

   c. Clay

   d. Rubber

10. The lead laying machine's wheel _____itself with leads, their spacing matching the grooves in the slats

    a. Loads

    b. Inserts

    c. Combines

    d. Turns

11. An automated _____flips each slat over, slides it across a glue applicator then drops it on to a leaded slat on the other conveyor belt

    a. Machine

    b. Table

    c. Belt

    d. Arm

12. All the steps to this point have culminated in what is effectively a lead _____

    a. Pancake

    b. Hotdog

    c. Sandwich

    d. Hamburger

13. A _____squeezes those sandwiches together with a full ton of pressure

a. Press

b. Plunger

c. Piston

d. Wheel

14. It compresses them for an hour while the _____dries

a. Paint

b. Rubber

c. Glue

d. Plastic

15. The _____machine makes the hexagonal profile in two steps,

a. Forming

b. Shaping

c. Molding

d. Carving

16. First, it's upper cutter forms three sides on top then it's lower cutter shapes three sides on the _____.

a. Right Side

b. Left Side

c. Top

d. Bottom

17. One at a time the pencils shoot through device called a _____ head

    a. Painting

    b. Lacquering

    c. Finishing

    d. Solvent

18. It coats the wood in paint, _____in this case

    a. Green

    b. Blue

    c. Yellow

    d. Red

19. The rubber tip assembly machine squeezes the top of the pencil to slide on a _____ferrule

    a. Copper

    b. Nickel

    c. Brass

    d. Aluminum

20. Then it inserts a rubber eraser into the ferrule's other end and _____that tight

    a. Smashes

    b. Squeezes

    c. Presses

    d. Glues

21. The pencils are finally ready to roll across the _____drum for sharpening

    a. Sanding

    b. Grinding

    c. Filing

    d. Cutting

22. By the time they _____off they're pointed perfection.

    a. Fall

    b. Roll

    c. Slide

    d. Pull

Appendix B

Video Content Test for *How It's Made: Sandpaper*

1. To make sandpaper, you need a lot of _____.
   a. Grit
   b. Sand
   c. Glass
   d. Teeth
2. There are thousands of tiny _____ grains on a single sheet.
   a. Circular
   b. Abrasive
   c. Sharp
   d. Metal
3. By rubbing the sandpaper against wood or metal, you can _____ defects and create a uniform surface.
   a. Erase
   b. Remove
   c. Hide
   d. Cover
4. Sandpaper often isn't made from paper at all, but _____ like poly cotton.
   a. Fabric
   b. Leather
   c. Plastic

d. Plants

5. The cloth is unwound into a machine with a/an

   a. Assembly line

   b. Hand wheel

   c. Printing press

   d. Ground plate

6. Rollers lined with rubber printers stamp _____ onto the cloth.

   a. Sand

   b. Resin

   c. Product information

   d. The manufacturer's logo

7. The cloth then travels underneath the printing press, where more rollers apply a heat-setting _____ to the unprinted side.

   a. Adhesive

   b. Rubber

   c. Resin

   d. Gel

8. A _____ measures the density of the coating to ensure that it's been applied correctly.

   a. Machinist

   b. Robotic scale

   c. Digital scanner

   d. Computerized system

9. Then the cloth is pulled one floor down to the _____ pit.

   a. Gravity free

   b. Electrostatic

   c. Radioactive

   d. Vibrating

10. Here, the environment is kept _____ -- perfect for applying grains to the cloth.

   a. Cold and dry

   b. Cold and humid

   c. Hot and dry

   d. Hot and humid

11. The conveyor moves the grains under the rolling cloth and between _____ and ground plates.

   a. Electrodes

   b. Radio waves

   c. Sensors

   d. LED's

12. The system generates a/an _____ that triggers a mini sandstorm.

   a. Wind tunnel

   b. Antigravity zone

   c. Electrical field

   d. Vibration space

13. Once airborne, the grains stick to the cloth and become _____ in it

   a. Entrenched

b. Trapped

c. Embedded

d. Entrenched

14. A technician cuts a _____ of the sandpaper, then peels away layers and makes three different cutouts.

a. Batch

b. Swatch

c. Sample

d. Strip

15. He weighs each cutout to confirm that the sandpaper has been formulated precisely to _____.

a. Measurement

b. Design

c. Requirement

d. Specification

16. He also examines the gritty surface under a _____ to confirm the grains are standing up evenly.

a. Light box

b. Microscope

c. Magnifying lens

d. Lateral sensor

17. This production run gets the go-ahead, so workers move the sandpaper through a hundred-yard-long _____.

a. Kiln

b. Stove

c. Oven

d. Furnace

18. It has three different heating zones, each progressively hotter. The increasing heat bakes the grains into the _____.

a. Cloth

b. Paper

c. Adhesive

d. Rubber

19. In the next step, a coat of _____ is rolled over the gritty surface, binding the grains to the base.

a. Glue

b. Resin

c. Epoxy

d. Adhesive

20. Some rolls are sliced into big sheets that are made into commercial sanding _____ – The kind used in heavy manufacturing.

a. Wheels

b. Drums

c. Blocks

d. Belts

21. Another machine punches out sanding _____.

a. Discs

b. Plates

c. Cards

d. Templates

22. And at another station, rolls of sandpaper are unwound into a machine that carves the layers into rectangles. These won't be used for sanding, but as grip tape for _____.

a. Diving boards

b. Nail files

c. Skateboards

d. Roofing shingles

Appendix C

Video Subtitle Text in *How It's Made: Pencils*

"The lead inside a pencil isn't actually lead. It's mostly graphite, which was discovered in England in the mid-1500's, giving birth to the pencil industry. In 1795, a French chemist invented a new type of pencil lead, made of graphite powder and clay fired in an oven, making it possible to produce leads with different hardness. For the pencils body, you need a type of wood that's soft enough to sharpen, yet strong enough not to bend under the writers hand pressure. This German pencil factory uses cedar from California. The wood is .2 inches thick and arrives pre-cut in slats of 7 x 2 ½ inches. One by one, the slats pass under a giant cutting wheel. It carves grooves that will become the channel down the middle that holds the lead. The next machine fills the grooves with glue, a special formulation that's slightly elastic. This cushions the lead so that it's less likely to break inside the channel. Every second slat moves onto another conveyor belt. The ones that stay on this line head toward the machine that lays in the lead. The lead is made of a graphite-and-clay mixture, baked in an oven at almost 1,500 degrees Fahrenheit. The lead laying machines wheel loads itself with leads, their spacing matches the grooves in the slats. It's the same process for colored pencils, only the leads are made of wax, clay, and pigments with no baking required. Now for the slats that move to that other conveyor belt. An automated arm flips each one over, slides it across a glue applicator, then drops it onto a leaded slat on to the other conveyor belt. All the steps to this point have culminated in what is effectively a lead sandwich. Now a plunger squeezes those sandwiches together with a full ton of pressure. It compresses them for an hour while the

glue dries. After that it's just a matter of slicing the sandwiches into pencils. This shaping machine makes the hexagonal profile in two steps. First, its upper cutter forms three sides on top, then it's lower cutter shapes three sides on the bottom. As soon as the bottom side is cut, the pencils separate. A worker pulls the sample pencil from each batch coming off the line and manually sharpens it to spot-check lead quality, then he applies force to the tip until it breaks. For a pencil to pass this strength test, it has to withstand at least 4 ½ pounds of force. Now it's time to dress that bare wood. One at a time, the pencil shoot through a device called a lacquering head. It coats the wood in paint, yellow in this case. It takes four coats of paint to completely hide the wood grain. A fifth lacquering head paints a black stripe, this company's trademark. Then a sixth head seals the paint job with a transparent lacquer. From the paint line, the pencils make their way to a stamping machine at an astounding rate of 500 pencils a minute. The machine heat- transfers foil lettering from a plastic film to the painted wood. Last stop -- the rubber-tip assembly machine. First, it squeezes the top of the pencil to slide on an aluminum ferrule. Then it inserts a rubber eraser into the ferrule's other end and squeezes that tight. European-style pencils have a painted cap instead, the color indicating how hard the lead is. After a coat of transparent sealer, the pencils take a series of dips in the first color, then, once that dries in the second color. The final coat is a high-gloss lacquer. The pencils are finally ready to roll… across a grinding drum for sharpening. By the time they roll off, they're pointed perfection. Looking as good as they perform, today's pencils sure have the right stuff" (Boyle & Hoss, 2008).

Appendix D

Video Subtitle Text in *How It's Made: Sandpaper*

"To make sandpaper, you need a lot of grit. There are thousands of tiny abrasive grains on a single sheet. The whole idea is to create friction. By rubbing the sandpaper against wood or metal, you can remove defects and create a uniform surface. It's ironic that something so abrasive can make things look so smooth and polished. Sandpaper often isn't made from paper at all, but fabric-like polycotton. The cloth is unwound into a machine with a printing press. Rollers lined with rubber printers stamp product information onto the cloth. The cloth then travels underneath the printing press, where more rollers apply a heat-setting adhesive to the unprinted side. A computerized system then measures the density of the coating to ensure that it's been applied correctly. Then the cloth is pulled one floor down to the electrostatic pit. Here, the environment is kept hot and humid -- perfect for applying abrasive grains to the cloth electrostatically. The grains are poured onto a conveyor belt in the pit. The conveyor moves the grains under the rolling cloth and between electrodes and ground plates. The system generates an electrical field that triggers a mini sandstorm. Once airborne, the abrasive grains stick to the adhesive coated cloth and become embedded in it. This method allows for even distribution of the grains across the cloth. The grain-coated cloth now rolls out of the pit and back up to the main level of the factory. A technician cuts a swatch of the sandpaper, then peels away layers and makes three different cutouts -- one of the cloth alone, another of the cloth with the adhesive coating, and a third the grain- and adhesive- coated cloth. He weighs each cutout to confirm that the sandpaper has been formulated precisely to

specification. He also examines the gritty surface under a microscope to confirm the grains are standing up evenly. This production run gets the go-ahead, so workers move the sandpaper through a hundred-yard-long oven. It has three different heating zones, each progressively hotter. The increasing heat bakes the grains into the adhesive. The sandpaper is now rough enough, but it's not quite ready for use. In the next step, a coat of resin is rolled over the gritty surface, binding the grains to the base. After the resin cured to the surface, these jumbo rolls of sandpaper are stored in a warehouse until it's time to cut them down to size. Some rolls are sliced into big sheets. These will be made into commercial sanding belts – The kind used in heavy manufacturing. Another machine punches out sanding discs. And at this station, four rolls of sandpaper are simultaneously unwound into a machine. It carves the four layers into rectangles. These rectangles won't be used for sanding, but as grip tape for skateboards. From refinishing your furniture to nose grinding at the skate park, sandpaper will give you an edge. And with so many grits to choose from, there really is sandpaper for every job" (Boyle & Hoss, 2008).