AC 2011-309: USE OF FINK'S TAXONOMY IN ESTABLISHING COURSE OBJECTIVES FOR A RE-DESIGNED MATERIALS ENGINEERING COURSE

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Use of Fink's Taxonomy in Establishing Course Objectives for a Re-designed Materials Engineering Course

Abstract

The course objectives for a Materials Engineering course were established using principles of course design from Fink [1]. In Fink's taxonomy, six different types of course objectives are possible. The different types include that of Foundational Knowledge, Application, Integration, Human Dimensions, Caring and Learning How to Learn. According to Fink's model for course design, a course should also include a Rich Learning Experience [1], or project, which addresses more than one course objective. The paper will discuss the changes that were made to the course and the approach to course re-design to allow for new course objectives. Assessment data for several of the objectives from two sections of the course will be presented. The course includes an audio podcast project, and data from the student evaluations of podcasts on materials topics will be presented.

Background

The Materials Engineering course that was modified is a three-credit required course for Mechanical Engineering sophomores. Seventy one students took the course during the Fall 2010 semester.

The approach to course re-design that was used was adapted from the work of Fink [1]. Fink has created an eponymous taxonomy that categorizes learning objectives into one of six types. The six distinct learning objective types, according to Fink, are: Foundational Knowledge, Application, Integration, Human Dimensions, Caring and Learning How to Learn. According to this methodology, re-designed courses should strive to incorporate at least one learning objective for each of the six categories. In addition to this course objective minimum requirement, a re-designed course should have a 'Rich Learning Experience', or project in which students are addressing more than one of the six designated learning objective categories. For example, for a Rich Learning Experience project in which students are performing a community service project involving recycling, they would be receiving a Caring type of learning (from the community service aspect) and an Application type of learning (from the materials recycling aspect).

In determining course objectives using the Fink's method, importance is placed on what is actually desired by the instructor, regardless of the outcomes' measurability. The Fink method challenges the instructor to determine the best way of assessing to what extent the outcome has been achieved.

Once course objectives are established, the objectives are written into a grid similar to that shown in Table 1. The column headings for the grid are 'Learning Objectives', 'Assessment Activities' and 'Learning Activities'. Using Fink's methodology, Learning Activities are written into the grid for each respective Learning Objective. Once the Learning Activities and Objectives are established, the final step is to fill in the center column of the grid by creating Assessment Activities for each of the Learning Objectives.

Table 1 lists the course objectives, assessment activities and learning activities that were created for the Materials Engineering course (MENG221) from the Fall 2010 semester.

For the re-designed course, the Rich Learning Experience was an audio podcast project, involving teams of students producing a materials podcast. The requirements of the podcast project are the same as that for podcasts submitted to ASM's podcast contest [2]. Podcasts must be between 1.5 and 3 minutes in length, and should be produced for a middle- or high-school science class as the target audience. Students in MENG221 were required to first listen to other award-winning materials podcasts, from the www.materialsradio.org website, to gain an example of what a well-produced podcast should sound like. Students were also required to evaluate the podcasts, as part of the listening assignment.

After producing their own podcasts, students in MENG221 were then required to listen to four other podcasts from their own cohort and provide an evaluation. Previous studies have shown that students gain pedagogical value from listening to their peers' podcasts [3]. The two top ranked podcasts from the semester were submitted to the ASM podcast contest [2].

The reason that the MENG221 podcast project is a Rich Learning Experience, according to Fink, is that it involves Learning How to Learn, Caring, Foundational Knowledge and Application types of learning. Traditional projects in materials courses, such as writing a research paper, may also be considered as a Rich Learning Experience. Course evaluation comments indicate that students show a relatively high enthusiasm level for a podcast project compared with that for a written report. It also appears that they start the project sooner than they would for a written report, although this has not been assessed.

The re-designed course included four 50 minute in-class, closed book quizzes and a two hour, closed book final exam. Data from each of these assessments is presented.

The objective of the investigation is to report the assessment results from an initial use of Fink's taxonomy in a re-designed Materials Engineering course. Continued work will feature outcomes assessment data for several academic years.

Table 1. MENG221 Course Objectives, Fall 2010

LEARNING OBJECTIVES	ASSESSMENT ACTIVITIES	LEARNING ACTIVITIES
Identify important sources of materials information **(LHTL)**	Quiz question	Podcast project
Be more interested in materials **(Caring)**	Podcast questionnaire	Podcast project
Respect their own abilities to make informed engineering decisions about materials **(Human dimension)**	Podcast questionnaire	
Describe the effect of atomic bonding on properties for a solid material. **(Integration)**	Homework, quizzes, final exam	Active learning exercises
Select the appropriate class of material for a general application. **(Integration)**	Homework, quizzes, final exam	Active learning exercises
Predict the effect of increased C on the mechanical properties of steel. **(Application)**	Homework, quizzes, final exam	Active learning exercises
Calculate weight fractions of phases in a microstructure from an equilibrium phase diagram, given an alloy composition and temperature. **(Application)**	Homework, quizzes, final exam	Active learning exercises
Determine phase compositions for all phases in a microstructure from an equilibrium phase diagram, given an alloy composition and temperature. **(Application)**	Homework, quizzes, final exam	Active learning exercises
Determine the ultimate tensile strength, yield strength, elastic modulus and ductility of a material given a plot of stress as a function of strain from a tensile test to failure. **(Application)**	Homework, quizzes, final exam	Active learning exercises
Predict the effect on properties from thermomechanical treatment on steels and aluminum alloys. **(Application)**	Homework, quizzes, final exam	Active learning exercises
Identify and classify the major types of solid materials. **(Foundational knowledge)**	Day 1 scavenger hunt	Day 1 scavenger hunt
List the three crystal structures. **(Foundational knowledge)**	Quiz and final exam data	

Assessment data

Table 2 summarizes the assessment data for the re-designed course based on Fink's course re-design method and taxonomy. Figure 1 shows the data from Table 2, normalized to allow for comparison. Many of the learning objectives were Application types (based on Fink's taxonomy). Typical Application objectives from MENG221 were based on students' ability to interpret phase diagrams or stress-strain diagrams. Most of the Application normalized average score from the Fall 2010 semester in from fig. 1 show relatively high scores. The first Application assessment item (indicated as 'Application_01' in the graph) was not assessed. The learning objective of 'Predict the effect of increased C on the properties of steel' was not assessed in the present study. The Learning How to Learn (LHTL) objective was not assessed, nor were either of the two Foundational Knowledge objectives. The data summarized in Table 2 and fig. 1 will continue to be gathered and compared on an annual basis, for ongoing assessment of MENG221.

Podcast project

In the second week of the semester, the students in MENG221 were required to listen to six award-winning materials podcasts from www.materialsradio.org. After listening to the podcasts, students were required to complete a questionnaire about the podcasts. The questionnaire asked students to assign a rating for the podcast in each of the four categories of 'Overall quality', 'Entertainment', 'Good for Kids' and 'Educational'. The ratings ranged from 10 (excellent) to 0 (poor). The students were also asked to circle which adjectives could be used to describe the podcast. There were twenty available adjectives from which to select. The list of adjectives is given in Table 3.

The six podcasts from www.materialsradio.org that were selected were the same six that were given to two sections of the same course, MENG221, (approximately 65 students) in the previous academic year, for the same podcast listening assignment. Because the podcasts are in the public domain, the titles of the podcasts and the names of the speakers have been changed to 'Podcast 1' through 'Podcast 6' in this publication. The podcasts were produced in 2007 and 2008 by Material Advantage chapters at several Universities in the US and other countries.

The evaluation data of the six podcasts for the back-to-back academic year cohorts allows for an insight into the repeatability of podcast evaluations.

Figure 2 shows a flow chart of how the podcast project was carried out during the Fall 2010 semester in MENG221.

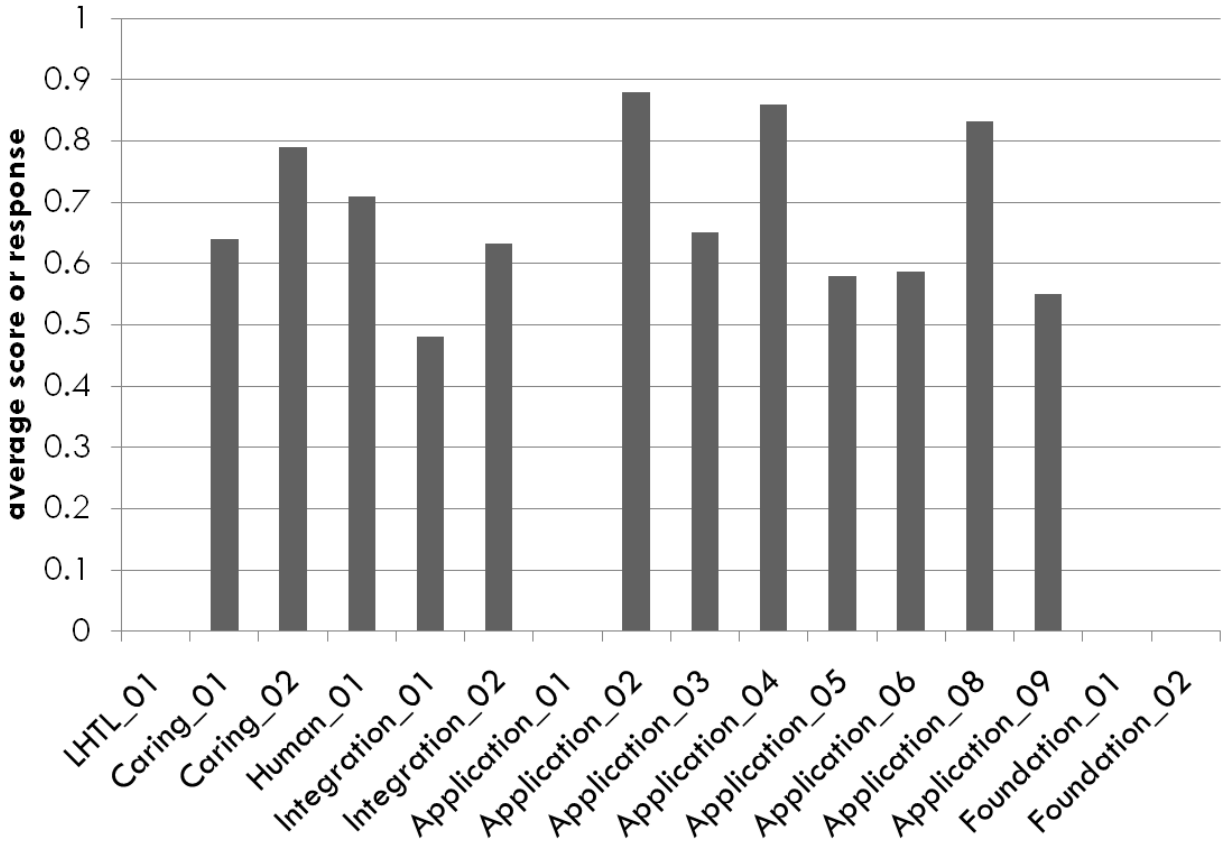

Fig. 1. Average score or response in assessment data. The data is taken from Table 2, and normalized for comparison. Some of the learning objectives (e.g. 'Application_01') were not assessed, so no data is shown for these objectives.

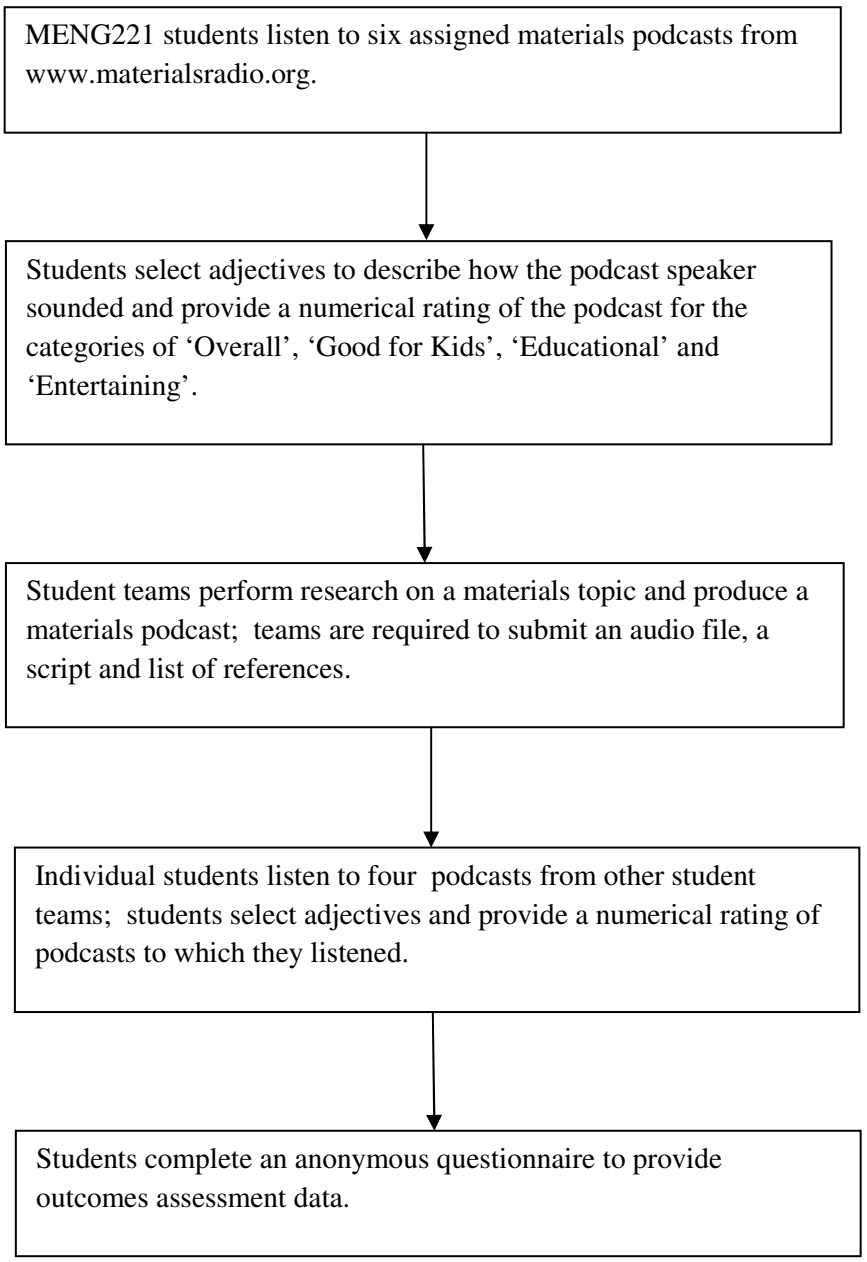

Fig. 2. Flow chart showing how the podcast project was carried out in MENG221 during Fall semester 2010.

Table 2. Summarized assessment data from MENG221

	Source	Results
Identify important sources of materials information **(LHTL)**		
Be more interested in materials **(Caring)**	Podcast questionnaire Q5	avg = 6.4 / 10
Be more interested in materials **(Caring)**	Podcast questionnaire Q6	avg = 7.9 / 10
Respect their own abilities to make informed engineering decisions about materials **(Human dimension)**	Podcast questionnaire Q7	Q7 avg = 7.1 / 10
Describe the effect of atomic bonding on properties for a solid material. **(Integration)**	Quiz 1 Problem 8	avg = 2.4 / 5 stdev = 1.1
Select the appropriate class of material for a general application. **(Integration)**	Quiz 4 Problem 4	avg = 9.5 / 15 stdev = 3.1
Predict the effect of increased C on the mechanical properties of steel. **(Application)**		
Calculate weight fractions of phases in a microstructure from an equilibrium phase diagram, given an alloy composition and temperature. **(Application)**	Quiz 2 Problem 2	avg = 8.8 / 10 stdev = 2.2
Calculate weight fractions of phases in a microstructure from an equilibrium phase diagram, given an alloy composition and temperature. **(Application)**	Final exam pg 10	avg = 7.8 / 12 stdev = 3.1
Determine phase compositions for all phases in a microstructure from an equilibrium phase diagram, given an alloy composition and temperature. **(Application)**	Quiz 2 Problem 4	avg = 12.9 / 15 stdev = 4.5
Determine phase compositions for all phases in a microstructure from an equilibrium phase diagram, given an alloy composition and temperature. **(Application)**	Final exam pg 9	avg = 2.9 / 5 stdev = 1.8
Determine the ultimate tensile strength, yield strength, elastic modulus and ductility of a material given a plot of stress as a function of strain from a tensile test to failure. **(Application)**	Final exam pg 6	avg = 4.7 / 8 stdev = 3.1
Predict the effect on properties from thermomechanical treatment on steels and aluminum alloys. **(Application)**	Quiz 3 Problem 4	avg = 20.8 / 25 stdev = 4.1
Predict the effect on properties from thermomechanical treatment on steels and aluminum alloys. **(Application)**	Final exam pg 11	avg = 1.1 / 2 stdev = 0.7
Identify and classify the major types of solid materials. **(Foundational knowledge)**		
List the three crystal structures. **(Foundational knowledge)**		

Table 3. Adjectives to describe how the podcast sounded

authoritative	boring	confident	conflicted
efficient	funny	happy	ignorant
melancholy	overconfident	professional	profound
scientific	silly	smart	strange
tired	underconfident	weird	wild

Table 4 summarizes the student evaluations of the six podcasts for each of the two academic years for which data was collected. The average rating is out of a maximum of 10. The number of ratings for each podcast and for each academic year ranges from 15 to 45.

Table 5 is the relative ranking of each podcast in each of the respective categories. For example, in the category of 'Entertainment', the Fall 2009 class rated Podcast 3 as the highest ranked podcast, on average, whereas the Fall 2010 class rated Podcast 2 as the highest ranked podcast. In the category of 'Good for Kids', both classes selected Podcast 2 as the highest ranked podcast. Also, from Table 4, the average 'Good for Kids' rating for for Podcast 2 for the Fall 2009 and Fall 2010 cohorts was 7.74 and 7.46 out of 10 respectively.

In Table 5, the two highest podcasts for average 'Overall Quality' are Podcasts 3 and 4 as determined by each of the two cohorts (Fall 2009 and 2010). Other notable agreements between the two cohorts are that Podcast 2 was ranked last in the 'Educational' category, and that Podcast 5 was at or near the bottom for the 'Entertainment' category.

Figures 3 through 8 are histogram charts of the adjective relative fraction for the most commonly selected adjectives for the six podcasts listened to by each of the Fall 2009 (black bars) and Fall 2010 (gray bars) cohorts. Figures 3 through 6 (Podcasts 1 through 4) show relatively good agreement in the selection of adjectives used to describe the podcasts. Figures 7 and 8 (Podcasts 5 and 6) indicate that the two class years have apparently different opinions regarding which adjective to select for these respective podcasts. An interesting observation regarding the adjective relative selection is that the adjective 'boring' is the most likely used adjective to describe Podcast 5 for both cohorts, and the second highest adjective for Podcast 6 for the Fall 2010 cohort. Also, Fall 2009 considered Podcast 6 to be the highest rated podcast for the 'Educational' category whereas the Fall 2010 cohort ranked it second from the bottom for this category.

Table 4. Podcast Listening Assignment Evaluation Data Summary

	count	avg	stdev	count	avg	stdev
Podcast 1	**F09**	**F09**	**F09**	**F10**	**F10**	**F10**
Overall quality	22	6.50	1.68	28	7.04	1.60
Entertainment	22	6.27	1.24	28	6.07	1.84
Good for kids	22	6.98	1.59	28	6.64	2.02
Educational	22	7.50	1.79	27	8.26	0.98
Podcast 2	**F09**	**F09**	**F09**	**F10**	**F10**	**F10**
Overall quality	23	7.41	1.23	26	7.42	1.45
Entertainment	23	6.78	1.70	26	6.81	1.65
Good for kids	23	7.74	1.45	26	7.46	1.88
Educational	23	7.43	1.97	26	7.23	1.61
Podcast 3	**F09**	**F09**	**F09**	**F10**	**F10**	**F10**
Overall quality	23	7.83	1.44	45	7.70	1.58
Entertainment	23	7.35	1.90	45	6.39	2.03
Good for kids	23	7.30	1.72	44	6.66	2.02
Educational	23	7.65	1.72	45	7.80	1.73
Podcast 4	**F09**	**F09**	**F09**	**F10**	**F10**	**F10**
Overall quality	24	7.79	1.32	41	8.18	1.17
Entertainment	24	6.42	2.00	41	6.73	1.60
Good for kids	24	6.71	1.78	41	6.78	2.14
Educational	24	7.92	1.53	41	8.20	1.50
Podcast 5	**F09**	**F09**	**F09**	**F10**	**F10**	**F10**
Overall quality	24	7.67	1.46	18	7.39	1.24
Entertainment	24	5.94	1.78	18	5.50	2.20
Good for kids	24	6.94	1.76	18	5.83	2.46
Educational	24	8.04	1.46	18	8.06	1.21
Podcast 6	**F09**	**F09**	**F09**	**F10**	**F10**	**F10**
Overall quality	22	7.55	2.09	15	6.53	1.92
Entertainment	22	6.86	1.70	15	5.07	1.87
Good for kids	22	6.86	2.42	15	5.20	2.46
Educational	22	8.14	2.10	15	7.33	1.59

Table 5. Ranked podcasts for each academic year

	Overall quality				**Entertainment**				**Good for Kids**				**Educational**	
	F09	**F10**			**F09**	**F10**			**F09**	**F10**			**F09**	**F10**
1	PC3	PC4		1	PC3	PC2		1	PC2	PC2		1	PC6	PC1
2	PC4	PC3		2	PC6	PC4		2	PC3	PC4		2	PC5	PC4
3	PC5	PC2		3	PC2	PC3		3	PC1	PC3		3	PC4	PC5
4	PC6	PC5		4	PC4	PC1		4	PC5	PC1		4	PC3	PC3
5	PC2	PC1		5	PC1	PC5		5	PC6	PC5		5	PC1	PC6
6	PC1	PC6		6	PC5	PC6		6	PC4	PC6		6	PC2	PC2

The parameter ‘adjective relative fraction’ from figs. 3 through 8 is the number of times an adjective is selected divided by the total number of adjectives given for that podcast. This new parameter, ‘adjective relative fraction’, is different that the parameter ‘probability of adjective selection’, as reported in [4]. The ‘probability of adjective selection’ from [4], is the number of times an adjective is selected to describe a given podcast divided by the number of student evaluations for that podcast. The new parameter ‘adjective relative fraction’ was developed as a better means of comparing the same podcast for two different cohorts of students since the number of student responses can vary from one year to another year.

References [5] and [6] are additional sources of materials podcast information, background and data.

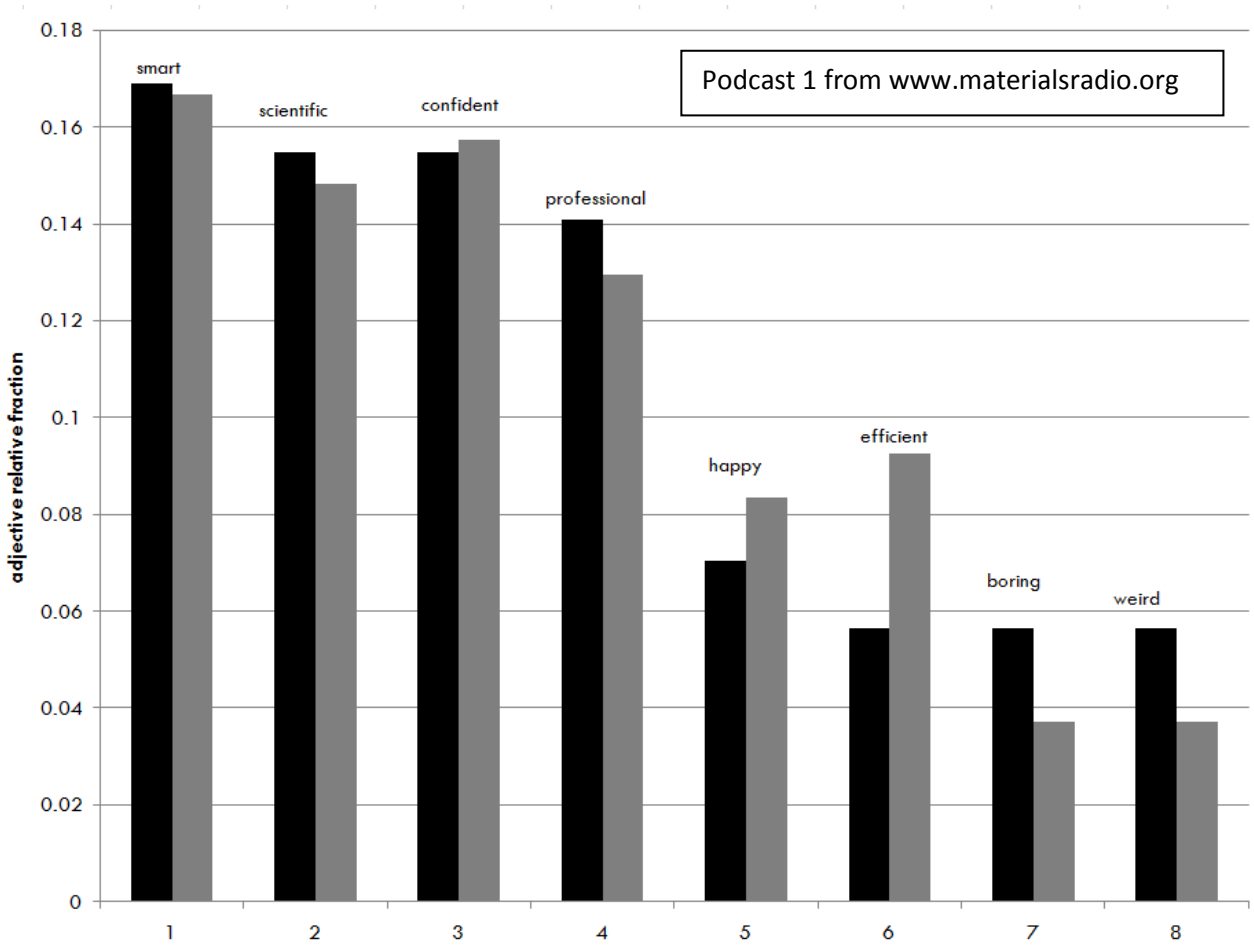

Fig. 3. Adjective relative fraction for Podcast 1, for Fall 2009 (black bars) and Fall 2010 (gray bars) cohorts. Relatively good agreement is shown for the two cohorts of students that selected adjectives to describe this podcast.

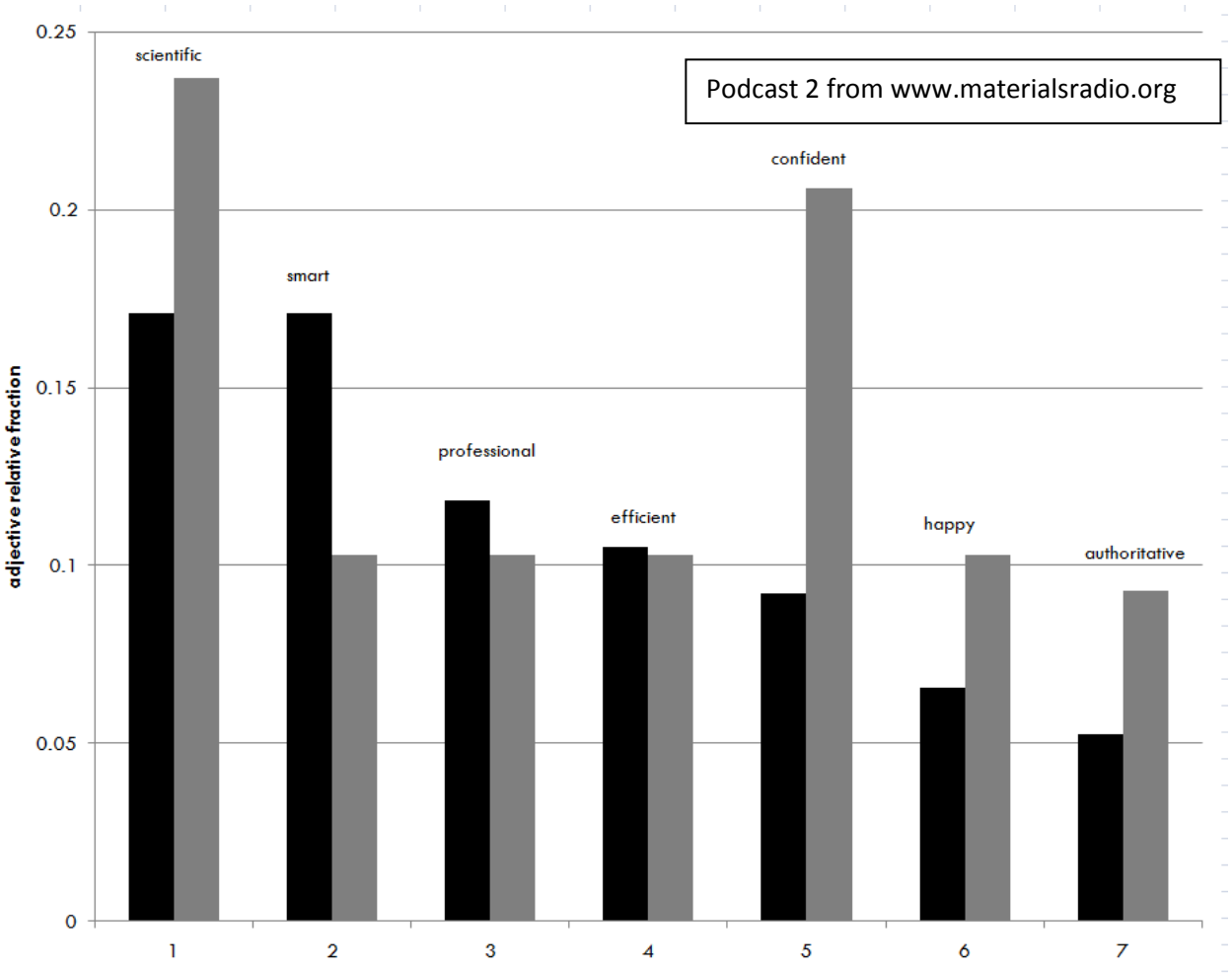

Fig. 4. Adjective relative fraction for Podcast 2, for Fall 2009 (black bars) and Fall 2010 (gray bars) cohorts.

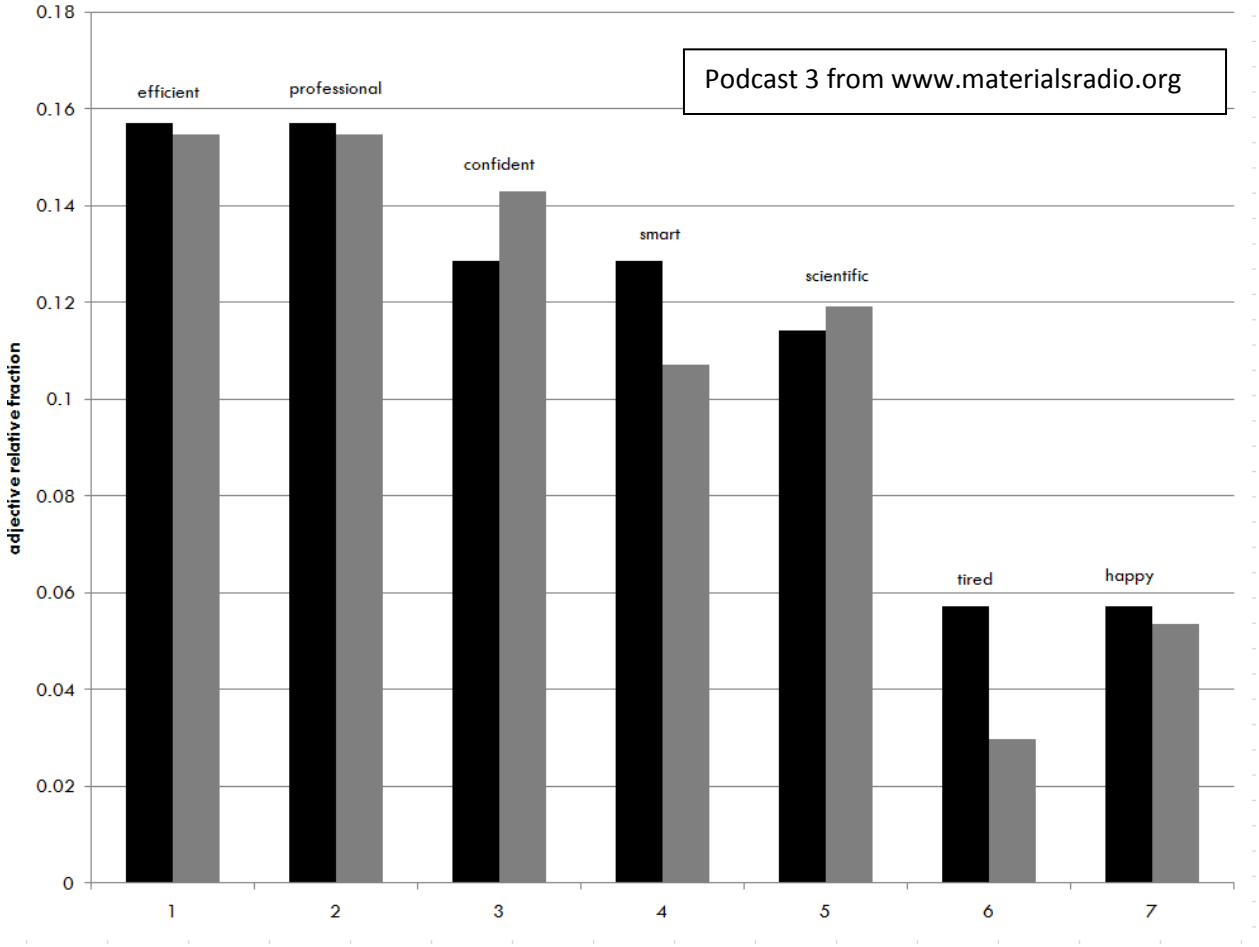

Fig. 5. Adjective relative fraction for Podcast 3, for Fall 2009 (black bars) and Fall 2010 (gray bars) cohorts. Relatively good agreement is shown for the two cohorts of students that selected adjectives to describe this podcast.

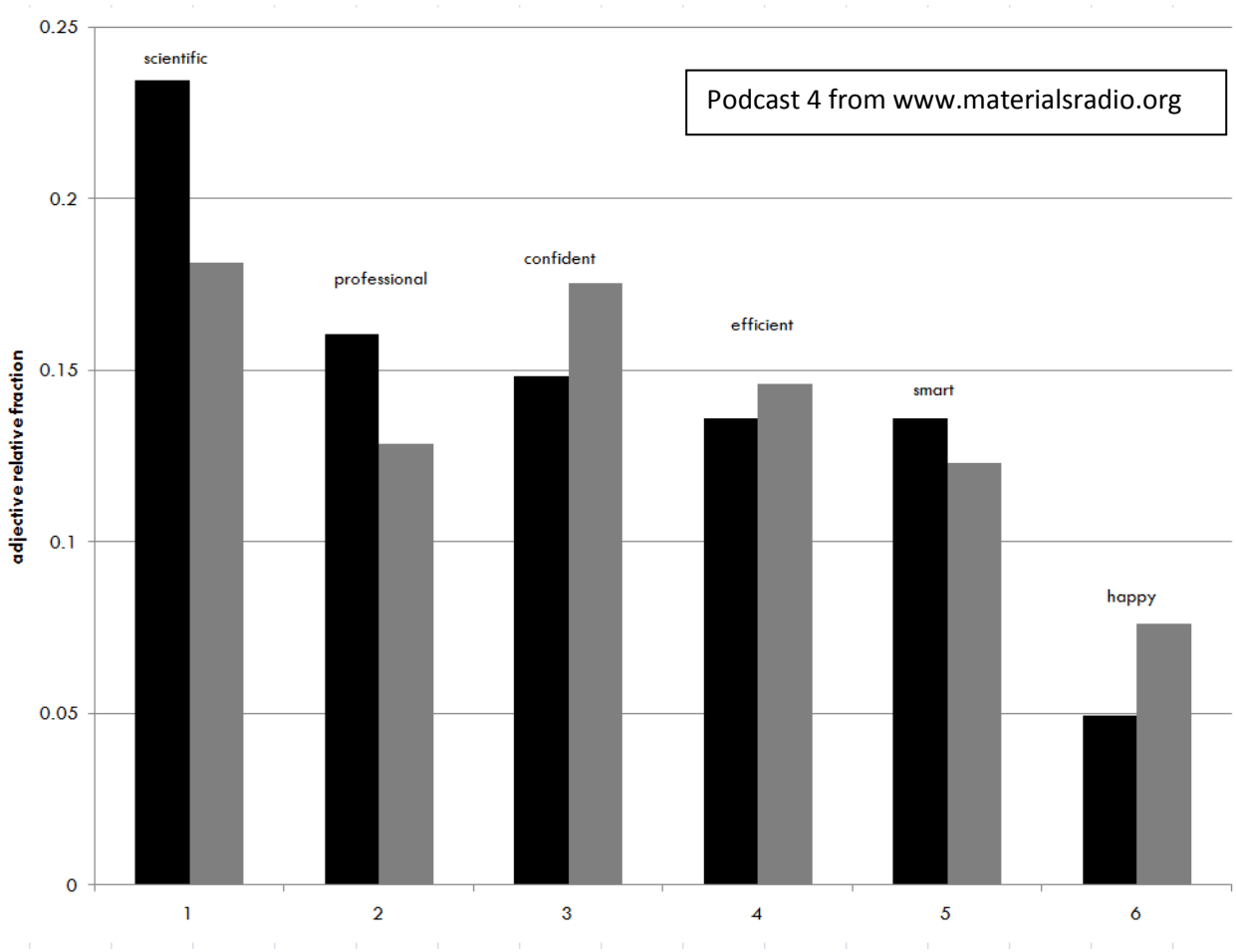

Fig. 6. Adjective relative fraction for Podcast 4, for Fall 2009 (black bars) and Fall 2010 (gray bars) cohorts.

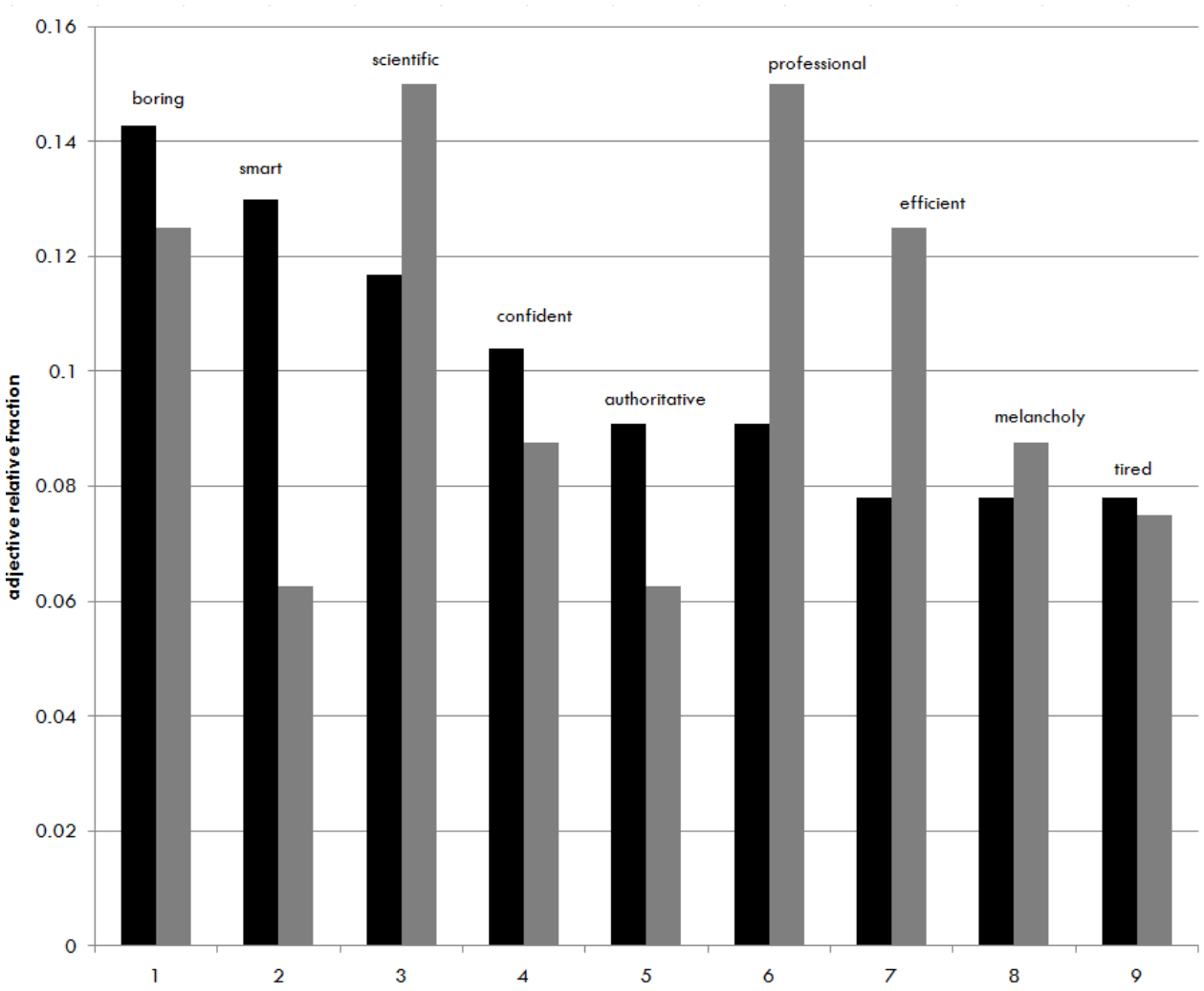

Fig. 7. Adjective relative fraction for Podcast 5, for Fall 2009 (black bars) and Fall 2010 (gray bars) cohorts.

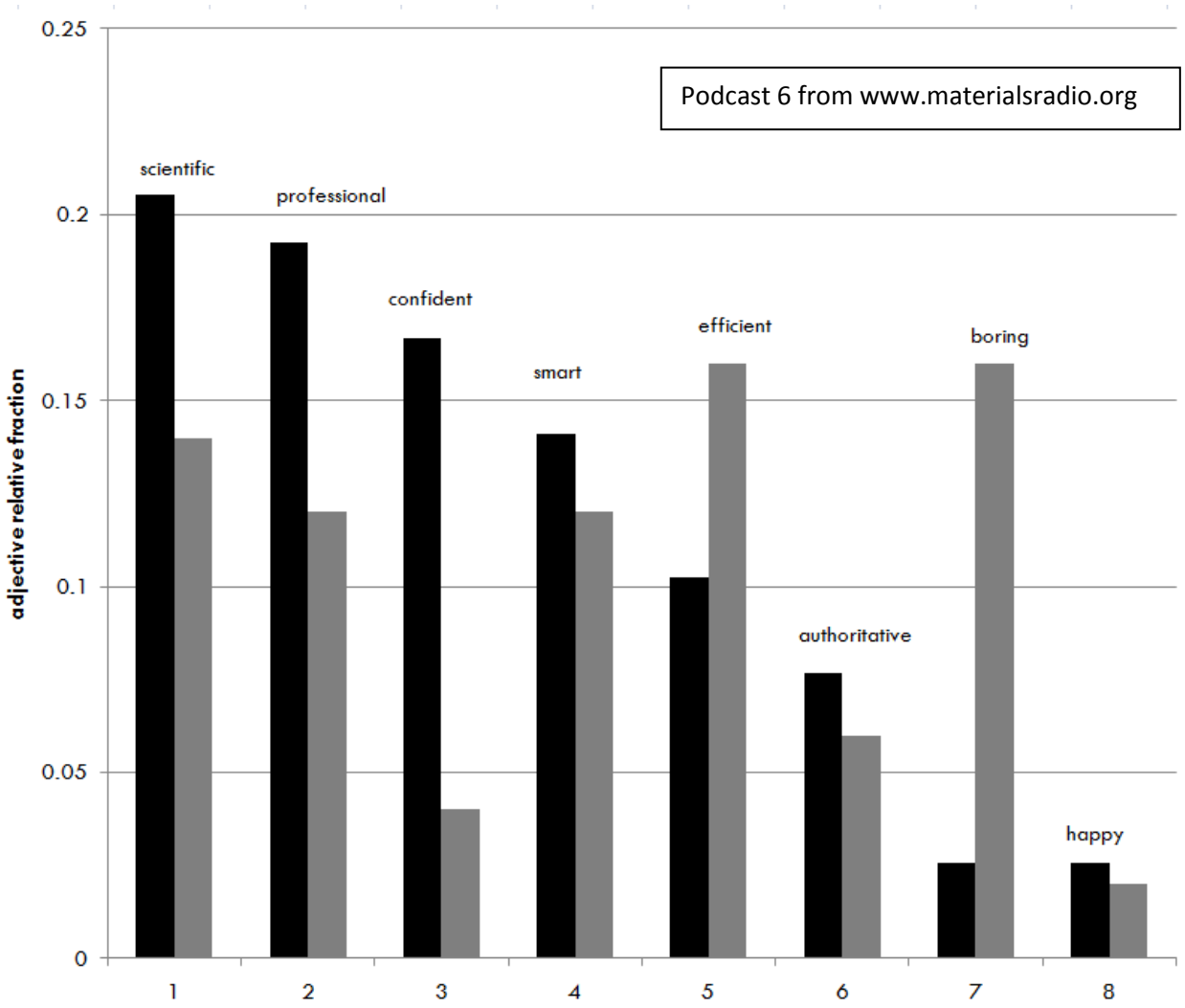

Fig. 8. Adjective relative fraction for Podcast 6, for Fall 2009 (black bars) and Fall 2010 (gray bars) cohorts.

After listening to podcasts, student teams were responsible for creating their own materials podcast and then listening to up to four other podcasts that were produced during the semester by their classmates. After listening to others' podcasts, students were required to evaluate the podcasts and complete a short questionnaire on their experiences in producing the podcast and on their own opinion of themselves as materials engineers.

Table 6 is the summary data from student evaluations of the podcasts from the Fall 2010 semester in MENG221. Each student was required to listen to four other podcasts, and provide an evaluation for each of the four categories of 'Overall quality', 'Entertainment', Good for Kids' and 'Educational'. The data in Table 6 shows the titles of the podcasts, and summary data for podcasts which had more than five evaluations. The podcasts are listed in order of number of student responses. Two of the podcasts were submitted to the ASM podcast contest. The two podcasts that were submitted were 'Aerogel' and 'Glidewax'.

Table 6. Podcast summary data from Fall 2010 MENG221student responses

	n, number of responses	Overall quality	Entertainment	Good for kids	Educational	Summed data
Kevlar	34	8.12	7.91	7.76	8.66	32.45
Samurai swords	28	7.79	7.5	7.07	8.29	30.65
Surfboards	26	8.58	8.54	7.81	8.42	33.35
Baseball bats	21	7.95	7.43	8.14	8.48	32
Contact lenses	21	8.45	7.19	7.29	8.48	31.41
Magnets	17	7.29	5.24	5.29	7.71	25.53
Frogskin	16	7.25	7.06	7.34	7.88	29.53
Glidewax	15	8.4	8.4	8.13	8.6	33.53
Fishing lines	14	7.71	6.33	6.87	7.67	28.58
Dirtbike frames	14	7.14	6.07	6.5	7	26.71
Aerogel	12	8.75	8.25	8.04	9	34.04
Lead	11	7.09	5.45	5.45	7.73	25.72
Non-newtonian fluids	8	7.75	7.5	7.5	9.13	31.88
Emulsion polymers	6	6.17	5.67	4.83	7.67	24.34

Table 7 summarizes the results of the podcast questionnaire student responses. The final question on the questionnaire asks students to rate their own ability to make engineering decisions about materials. The data was used as part of the assessment of the Learning Objective, 'Respect their own abiltiy to make informed engineering decisions about materials'. According to the Fink's taxonomy, this type of learning objective is one of Human Dimension. According to the data from the student questionnaires, the average response 7.12 out of 10. This data will continue to be monitored on an annual basis. Reference [4] has summarized data from the Fall 2009 cohort.

Questions 5 and 6 from the podcast questionnaire asked students to rate their own interest in materials before and after participating in the podcast project. The average answer before participating in the project is 6.4 out of 10, and jumps to 7.9 out of 10 after participating in the project. The data is used to assess the learning objective 'Be more interested in materials', which is a Caring type of learning objective per Fink. The response data for Questions 5 and 6 preliminarily indicates that the podcast project may be effective at increasing student interest, which may be useful in obtaining the result of having students learn more about materials.

The data in Table 7 preliminarily indicates that the podcast project, by itself, does not appear to be the most effective way of helping students learn complex subjects. For example, the average response for 'listening to an audio podcast' is only 6.17, the lowest average response compared to all of the other choices represented between Q3a and Q3g. However, the entire podcast

project involves more than listening to a podcast. The project involves listening to a group of podcasts from previous years, assigning ratings and selecting adjectives, creating a podcast (with references), listening to peers' podcasts and assigning ratings to peers' podcasts. Taken altogether, the podcast project may be effective in increasing interest in materials, which may be a necessary step to learning more about materials.

An important aspect of the podcast work that is not addressed is an investigation of how well podcasts help middle school students learn about materials. The assessment of middle school students' achievement of learning objectives is outside the scope of the present investigation but may be considered for future research.

Table 7. Summarized student responses to podcast questionnaire

	Question 1=none 3=not very much 5=neutral 7=some 10=great amount	n, responses	$\bar{x}$, average response
Q1	How much did listening to a podcast reinforce your understanding of materials?	77	7.13
Q2	How do you think that participating in the podcast project enriched your engineering education?	78	7.03
Q3	Using the numerical scale, assign a rating to how well you think each of the following media or settings are in helping your learn a complex subject:		
Q3a	reading the textbook	78	6.63
Q3b	listening to an audio podcast	78	6.17
Q3c	watching an internet video	78	7.08
Q3d	doing a research project involving internet searching	78	7.42
Q3e	listening to a good professor in a classroom	78	8.79
Q3f	listening to an average professor in a classroom	78	6.57
Q3g	small group discussion with other students and nearby instructor	78	6.93
Q5	On a scale of 1-10, where 1=not interested and 10=extremely interested, rate your interest in materials ***before*** participating in the podcast project	72	6.37
Q6	On a scale of 1-10, where 1=not interested and 10=extremely interested, rate your interest in materials ***after*** participating in the podcast project	71	7.93
Q7	On a scale of 1-10, where 1=not very able and 10=extremely able, rate your own ability to make informed engineering decisions about materials as a result of taking this course	69	7.12

Conclusions

Fink's taxonomy was used to re-design a Materials Engineering course. The learning objectives that were created were assessed through exams and podcast questionnaires. Data from the audio podcast project was used to determine the repeatability of student evaluations of podcasts. The assessment data shows that most of the learning objectives are being satisfactorily achieved. The podcast questionnaire data indicates that students are more interested in materials after participating in an audio podcast project.

References

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