2006-1507: APPLYING K-8 SCIENCE AND TECHNOLOGY CURRICULA TO ENGINEERING EDUCATION: WHAT CAN BE LEARNED FROM THE EDUCATOR RESOURCE CENTER AT THE MUSEUM OF SCIENCE, BOSTON

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Applying K-8 science and technology curricula to engineering education: What can be learned from the Educator Resource Center at the Museum of Science, Boston

The National Research Council and the International Technology Education Association have established standards for technological literacy, and several states require engineering concepts to be taught and assessed on state tests. Each year sees the publication of more curricular materials to address these standards, but many teachers and districts lack the resources or time to determine which curriculum is most appropriate for the learning needs of their students. The primary goal of this study is to consider the usefulness of traditional science and technology curricular materials for K-8 educators who are interested in addressing engineering content standards.

This paper describes an analysis of selected K-8 science and technology curricula in the context of teaching engineering. The set of curricula considered here is a convenience sample: an online database of K-8 science and technology textbooks and teacher's guides that have been reviewed by the Educator Resource Center at the Museum of Science, Boston, according to their appropriateness for teaching about engineering. Each curriculum was previously evaluated according to 20 criteria by the Educator Resource Center (ERC). These 20 evaluation parameters measure six key characteristics: coverage of national and state standards, usability by K-8 teachers, adequacy of background information and educator support, availability of different amounts of scaffolding for student activities, variety of instructional approaches to the design process, and provision of assessment tools. In this meta-analysis, evaluations of 44 different curricular modules are compiled, and summary statistics of the entire sample set and specific subsets are computed and compared. The paper concludes with recommendations for the application of ERC-reviewed science and technology curricula to K-8 engineering education. It also identifies the national and state engineering/technology standards that are currently not addressed by the ERC science and technology textbooks and teacher's guides.

1. Introduction

1.1 Background Information and Literature Review

A new trend in K-12 education is to incorporate concepts and ways of thinking from the engineering disciplines into math and science courses. A growing number of educators, starting at the postsecondary level and now spreading to the high school and elementary level, are recognizing that awareness of and knowledge about engineering are crucial to students' ability to navigate our technology-dependent society. This effort by educators and policymakers to include engineering in K-12 classrooms is part of an initiative that is often referred to as the "technological literacy" movement.

The modern technological literacy movement can be said to have begun in 1996, when the International Technology Education Association (ITEA) and the National Science Foundation published the *Technology for All Americans Project, A Rationale and Structure for the Study of Technology*[1]. Specific recommendations about the content of technology education were made in 2000, when the National Research Council joined with the ITEA to establish national standards for technological literacy [2]. Two years later, the National Research Council published two studies that convincingly make the argument for K-12 engineering education. These studies are *Raising Public Awareness of Engineering*, and *Technically Speaking: Why All Americans Need to Know More About Technology* [3,4].

As a result of these and other advocacy efforts, several states, including Massachusetts, require engineering/technology concepts to be taught and assessed on state tests [5]. Each year sees the publication of more curricular materials to address these standards, but many teachers and districts lack the resources or time to determine which curriculum is most appropriate for the learning needs of their students.

Professional development seminars at nearby colleges of engineering are one way for K-12 teachers to gain competence in selecting and leading engineering activities. However, not all teachers live near or have access to colleges of engineering. To introduce engineering concepts and processes into their instruction, many teachers will simply add lessons from traditional textbooks or curriculum kits. Thus, an important question is: which traditional textbooks and kits are the most useful for teaching engineering concepts? Unfortunately, most primary and middle grade teachers have limited experience with engineering and technology and do not have the resources to evaluate different options and determine the best activities to adopt. These K-8 teachers in particular (as compared with high school teachers) may find themselves unprepared for the engineering/technology standards that are being adopted by more and more states.

To alleviate this problem, many groups have published collections of K-8 curricular activities that address engineering or technology topics. These are both in print and online. One of the largest of these efforts is the TeachEngineering Digital Collection [6], which is a part of the National Science Foundation's National Science, Technology, Engineering, and Mathematics Digital Library (NSDL) program. The online TeachEngineering collection features multi-week curricular units as well as stand-alone one-day lessons, and all of its instructional materials are cross-referenced with national and state science, math, and engineering/technology standards. The TeachEngineering collection does include brief user reviews for a small number of its activities, and it indicates the number of standards addressed by each activity. While it is a very important collection, TeachEngineering does not provide comprehensive evaluations of its materials. Interested teachers can read through the activity description and estimate how engaging the activity will be, how much teacher support is provided by the resource, and how open-ended the student activities and assessments are, but they have no advance information about other teachers' opinions of the materials.

Another large digital library of classroom activities related to engineering and technology is the PreK-12 Engineering online library [7], which is a product of the Massachusetts Department of Education in partnership with the Tufts University Center for Engineering Educational Outreach. The PreK-12 Engineering website was designed specifically with Massachusetts teachers in mind, and it provides detailed engineering activities that are cross-referenced with Massachusetts state standards. Like the TeachEngineering collection, this website does not provide evaluations or reviews of its activities.

In addition to the TeachEngineering and PreK-12 Engineering programs, many university groups have created K-12 engineering lessons and have published them online. The more extensive TeachEngineering and PreK-12 Engineering programs are large digital libraries of instructional materials created by many different educators, whereas these university-sponsored websites typically contain only self-authored, stand-alone lessons that may or may not be aligned with national and state standards.

TeachEngineering, PreK-12 Engineering, and other digital collections are all valuable tools for K-8 educators who are looking for lessons and instructional sequences to address specific engineering/technology standards. However, many teachers may rely on traditional textbooks and teacher's guides that were designed primarily for science education. Digital collections of engineering-specific lessons are growing in popularity, but in the meantime, educators may want to apply traditional science and technology textbooks to engineering/technology standards.

Where can science and technology educators turn to make informed decisions about the most appropriate textbooks and teacher's guides for the engineering units and lessons that they conduct in their classrooms? One tool is the Educator Resource Center (ERC) at the Museum of Science, Boston, which is a collection of textbooks, teacher's guides, websites, museum exhibits, and other multimedia products for science, math, technology, and engineering education. These resources have been compiled into the "Educator Resource Center Online", a searchable online database within the Museum's website[8]. One difference between the ERC Online and other digital collections of curriculum materials is that many of the ERC's resources have been subjected to rigorous reviews by independent evaluators. Practicing educators review the resources according to their mappings to national and state standards, the types of activities used, the design approaches implemented, and the assessment types employed. The ERC's evaluation criteria are specific to the needs of educators who are trying to address the content and processes of engineering/technology.

Several other educational research organizations have set the precedent for the Museum's curriculum review initiative. In the science and technology education communities, curriculum experts have published evaluations of textbooks and other curriculum materials. One highly-regarded set of curriculum reviews is the middle school science textbook evaluation conducted by the "Project 2061" program of the American Association for the Advancement of Science [9]. They analyzed nine widely-used middle grade science programs (textbooks and teacher's guides) and found none of them to be satisfactory. In a 1997 report, they describe their evaluation tool: each program undergoes a preliminary inspection, a content analysis (how well are standards covered?), an instructional analysis (is student learning likely to occur?), and a summary report[10]. Another method for evaluating science curriculum is suggested by professional development specialist Page Keeley, in her book *Science Curriculum Topic Study*. Keeley provides a list of 20 questions that educators should use as part of an initial screening process for curriculum, before engaging in or consulting a more thorough curriculum analysis (Keeley, 2005). The intended audience for these 20 questions is those educators who make curriculum decisions for their school or district. One other organization that has developed a curriculum analysis procedure is the Education Development Center, which offers a framework to help educators select mathematics curricula [11].

The curriculum review that addresses the audience most similar to the audience of the Educator Resource Center is Edward Britton's *Bringing Technology Education into K-8 Classrooms: A Guide to Curricular Resources about the Designed World* [12]. This is a joint publication of the International Technology Education Association, the National Science Teachers Association, and WestEd. It is a comprehensive and important book with a focus on curriculum materials that were designed specifically for technology education. Educators who are interested in the application of more traditional science curricula to engineering topics, or who are curious about the usefulness of materials designed specifically for engineering lessons, may find that some of their questions are not within the scope of Britton's book. The Educator Resource Center at the Museum of Science, Boston, offers an additional tool for K-8 educators who are introducing engineering and technology into their classrooms.

1.2 Motivation for and Explanation of the Study

K-8 teachers would benefit from decision-making tools for incorporating engineering concepts and activities into their classrooms. The Educator Resource Center (ERC) has done the work of collecting and evaluating dozens of science and technology educational resources that have some relevance to engineering standards. In this present study, I take advantage of the ERC by quantitatively analyzing its reviews of K-8 science and technology curricula as they relate to engineering teaching. I hope to assist educators in choosing instructional materials to cover engineering and technology standards. How can we summarize the strengths and weaknesses of K-8 science and technology curricula as they apply to teaching engineering processes and concepts? What types of K-8 science and technology instructional materials receive the best reviews in the context of engineering teaching? Where might science and technology curriculum developers focus future efforts in order to ease the process of integrating engineering into K-8 instruction and in order to address gaps in engineering standards coverage?

In Massachusetts, these questions are especially important because the Massachusetts Comprehensive Assessment System (MCAS) tests now include questions that explicitly address engineering/technology frameworks. Many curriculum developers have created science textbooks that include engineering and technology ideas, but many K-8 teachers have limited experience with engineering or do not have the resources to evaluate different options and determine the best activities to adopt. The Educator Resource Center has attempted to help with this challenge by reviewing as many educational resources as possible in an context. Each reviewed textbook or teacher's guide is evaluated according to the number of engineering/technology standards (national and state) that it meets, its usability, its educator support, the types of activities included, the types of design approaches used, and the types of assessments provided. These comprehensive, quantitative evaluations are published on the ERC website. While these evaluations are a powerful tool for teachers considering specific materials, the ERC lacks a summary report of all its K-8 engineering-related resources. Teachers might find useful a compilation of all the evaluations of engineering-related curricula, in addition to the individual evaluation reports that are currently available. Furthermore, such a compilation may help K-8 engineering curriculum developers establish focus areas for future work.

Intentionally, the compilation produced by this study is generated from a "convenience" sample. In other words, I have not randomly selected materials from a long list of engineering curricula but instead have chosen the entire set of ERC-reviewed materials that meet the criteria of (1) at K-8 grade level, (2) in the format of textbook or teacher's guide, and (3) described by "engineering" as a keyword. The primary motivation for use of this convenience sample is that it lends itself easily to meta-analysis; all of the materials in the sample have already been reviewed by the ERC's consistent and quantitative external evaluation process. Further justification for using this particular convenience sample is the familiarity that K-8 educators already have with the types of textbooks and teacher's guides included in the ERC. Several of the curricular series that appear in this study's sample set – especially the Full Option Science System (FOSS), Great Explorations in Math and Science (GEMS), and Science and Technology for Children (STC) – are already widely used by public school science programs and are showcased at conventions of the National Science Teachers Association. The adoption of an engineering-specific curriculum, in addition to a traditional science/technology textbook, requires a substantial investment of time, energy, and possibly funds. Therefore, it is important for educators first to determine the extent to which already-owned or readily available science and technology curricula can be applied to engineering education. It is the goal of this study to consider the usefulness of commonly recognized science and technology curricular materials for teaching engineering. The use of the convenience sample of ERC-reviewed materials allows this study's sample set to fall primarily into this category of familiar and common science and technology materials.

1.3 Main Goals of the Study

This study uses the Educator Resource Center to explore two specific questions: 1) Is a material's appropriateness for teaching engineering correlated with the specific characteristics of publication date, intended grade level audience, module duration, or publisher's curricular series? and 2) What are the national and state engineering/technology standards that are currently not addressed by the ERC's engineering-related curricular materials? In answering these two questions, this study makes recommendations for the selection of science and technology curricula for engineering lessons and for the development of new engineering curricula.

2. Methods

2.1 Sample Set

To investigate the usefulness of existing science and technology curricula for K-8 engineering education, this study examines a subset of the Educator Resource Center Online, a digital collection of curriculum descriptions and reviews produced by the Museum of Science, Boston. The ERC has identified hundreds of resources that it believes will be effective tools for educating students about engineering. The sample used in this study consists of a convenience sample of 44 of the ERC's educational resources, which were chosen using the "advanced search" function of the ERC database. The 44 materials comprise the entire set of ERC materials that satisfy all four of the following selection criteria: (1) intended for one or more grade levels between K and 8, (2) classified as a *textbook* or *teacher' guide*, (3) includes "engineering" as a keyword, and (4) subjected to evaluation process by MoS curriculum reviewers. The modules in the sample set all fit into one of eight different curricular series or author groups. These groups include seven actual series titles and one additional category for the independent textbooks that are not part of a publisher's series. Table 1 lists all eight of these author/series groups.

Table 1. The eight authors/curricular series included in the sample of 44 modules.

Abbreviation	**Program Name**	**Description**
After School	Independent, stand-alone after school program	Created by the Center for Science Education. Published by Kelvin.
City Tech	Stuff that Works! City Technology Curriculum Guides	Created by Benenson & Neujahr at City College of New York. Published by Heinemann.
FOSS	Full Option Science System	Created by Lawrence Hall of Science. Published by Delta Education.
GEMS	Great Explorations in Math and Science	Created by the Lawrence Hall of Science. Distributed by Carolina Biological Supply.
IMaST	Integrated Mathematics, Science and Technology Project	Created by CeMAST at Illinois State University. Published by RonJon Publishing.
Indep. Text	Independent, stand-alone, year-long technology textbooks	Various authors and publishers.
SAE	Society of Automotive Engineers Design Challenges	Created with help of Education Development Center. Distributed by SAE.
STC	Science and Technology for Children	Created by National Science Resources Center out of the National Academies. Published by Carolina Biological Supply.

2.2 Data Collection Procedures

Each of the 44 curriculum reviews contains the same types of quantitative data. The MoS reviewers followed essentially the same analysis procedure that Britton and his colleagues followed in their review of K-8 technology curriculum materials (Britton, *et al.* 2005). Table 2 outlines the evaluation rubric applied to each reviewed ERC curriculum material. Each review contains 20 evaluation parameters: 2 standards categories, 1 usability score, 1 support score, 8 assessment type percentages, 3 activity type percentages, and 5 design approach percentages. In addition to the direct ERC data, I computed two more evaluative parameters for each resource: percentage of national standards met *per week*, percentage of state frameworks met *per week.*

Each of the 44 reviews in the sample under study was downloaded from the ERC website, and each of the pieces of quantitative data listed in Table 2 was extracted and entered into a spreadsheet. Next, the two derived parameters were computed. Finally, four independent descriptors were assigned to each curriculum material: intended grade level audience, publication year, duration of instruction, and author or curricular series (e.g., “Full Option Science System” from Lawrence Hall of Science). In the final spreadsheet, each of the 44 curriculum materials was described by four independent characteristics and 22 dependent parameters. In addition to the evaluation parameter values, the exact standards and frameworks met by each module were also extracted from the ERC review and entered into a spreadsheet.

Table 2. Curriculum analysis procedure used by the Educator Resource Center at the Museum of Science, Boston[8]

Evaluation Criteria	Categories	Scale
Standards Addressed	% of National *Standards for Technological Literacy* met	0% - 100%
	% of *Massachusetts Science and Technology/Engineering Frameworks* met	0% - 100%
Usability Score (Average of scores in all five categories)	Average cost of supplies	1 = Over $50 → 4 = No cost
	Source of supplies	1 = Special order → 4 = At school
	Set-up time per activity	1 = Over an hour → 4 = Less 15 min.
	Classroom management for activities	1 = Unclear → 4 = Well-defined tasks
	Activity safety	1 = Dangerous → 4 = Clear warnings
Teacher Support Score (Average of scores in all five categories)	For teaching the curriculum	1 = Curriculum provides no support for teacher → 4 = Curriculum provides full support for teacher
	For pedagogy	
	For assessment	
	For teaching technological standards	
	For teaching employability skills	
Assessment Types	Paper and pencil	0% - 100%
	Open ended questions	0% - 100%
	Portfolios, records, journal	0% - 100%
	Performance-based	0% - 100%
	Interview	0% - 100%
	Student presentation	0% - 100%
	Discussion	0% - 100%
	Other (rubrics, writing activities, etc.)	0% - 100%
Activity Types	Open ended	0% - 100%
	Guided	0% - 100%
	Recipe	0% - 100%
Design Approaches	Full scale design	0% - 100%
	Scaffolded design	0% - 100%
	Redesign, modify, improve	0% - 100%
	Investigate	0% - 100%
	Practical warm-up	0% - 100%

2.3 Data Analysis Methods

The first step in analyzing the data was to compute the mean and standard deviation of each of the 22 evaluation criteria. Then, ANOVA testing was used to explore whether the values of these evaluation parameters depend on any of the four independent characteristics mentioned above (grade level, publication year, module duration, and author/series). The curriculum materials were divided into groups according to these four factors. Eight single-factor ANOVA tests were carried out for each of the four independent variables. The eight dependent variables were (1) total percentage of national standards met, (2) percentage of national standards met weekly, (3) total percentage of state frameworks met, (4) percentage of state frameworks met weekly, (5) usability score, (6) educator support score, (7) proportion of paper and pencil assessments, and (8) proportion of portfolio or journal assessments. After the ANOVA tests determined if groups differ significantly with respect to these eight variables, the Tukey mean comparison method was used to compare individual pairs of group means. For example, when the ANOVA test for usability score vs. grade level returned a significant p-value, then the mean usability score from each grade level was compared to each of the other grade level mean scores (and a Student's t-test was conducted).

This study's second set of results deals with the coverage of specific content. For grades K-2, there are 7 Massachusetts state frameworks for engineering/technology and 43 ITEA national standards of technology literacy. For grades 3-5, there are 9 state frameworks and 58 national standards. For grades 6-8, there are 34 state frameworks and 86 national standards. Using the data on the specific standards and frameworks addressed by each module, the percentage of the grade-appropriate modules meeting each of the standards and frameworks was computed.

3. Results

3.1 Comprehensive Description of ERC-Reviewed Curricula for Engineering Education

The first set of results includes the summary descriptive statistics for the overall group of textbooks and teacher's guides reviewed by the Educator Resource Center (ERC) in the context of K-8 engineering education. These summary statistics help describe the usefulness of ERC-reviewed science and technology curricular materials for K-8 engineering education. Table 3 lists the mean and standard deviation for each of the 22 parameters used to evaluate the curricular materials.

Table 3. Summary descriptive statistics for entire group of K-8 engineering-related curriculum materials reviewed by the Educator Resource Center at the Museum of Science, Boston.

Variable	Mean (n=44)	Std. Dev.
% of National Standards Met Overall	0.41	(0.26)
% of MA Frameworks Met Overall	0.50	(0.27)
% of National Standards Met per Week	0.068	(0.076)
% of MA Frameworks Met per Week	0.090	(0.099)
Usability Score	2.70	(0.59)
Educator Support Score	3.07	(0.66)
% Activities that are Open-Ended	0.23	(0.20)
% Activities that are Guided	0.46	(0.21)
% Activities that are Recipe	0.30	(0.19)
% Design Approaches that are Full-scale	0.21	(0.20)
% Design Approaches that are Scaffolded	0.20	(0.17)
% Design Approaches that are Redesign	0.10	(0.12)
% Design Approaches that are Investigate	0.35	(0.24)
% Design Approaches that are Warm-Up	0.13	(0.15)
% Assessments that are Paper & Pencil	0.19	(0.36)
% Assessments that are Open-Ended	0.24	(0.28)
% Assessments that are Portfolios, Journals	0.54	(0.27)
% Assessments that are Performance-Based	0.49	(0.23)
% Assessments that are Interview-Based	0.03	(0.07)
% Assessments that are Presentations	0.10	(0.14)
% Assessments that are Discussion-Based	0.32	(0.30)
% Assessments in "Other" Category	0.23	(0.33)

The most straightforward results tell us about the usability and educator support levels of the materials and the proportion of grade level standards and frameworks met weekly. The mean usability score for the K-8 engineering-related resources is 2.70 out of 4. The mean educator support score is 3.07 out of 4. On average, the modules covered 6.8% of the grade-appropriate national standards per week and 9.0% of the grade-appropriate state frameworks per week.

The results concerning classroom design activities, design approaches, and assessments indicate which engineering education pedagogical strategies are most popular among the ERC-reviewed materials. The most common scaffolding level given to classroom activities is "guided." On average, 46% of a module's activities are "guided," while 30% are "recipe," and 23% are "open-ended." The most frequent type of design challenge uses the "investigate" approach. On average, 35% of a module's design challenges require students to investigate how an artifact or system functions. The most common assessment methods are performances and portfolio or journal evaluations. These methods typically comprise 49% and 54%, respectively, of a module's assessments.

To investigate whether the outcome of a curriculum review can be predicted by any specific factors, the summary descriptive statistics were compared across different categories of curriculum materials. Four different independent characteristics were used to describe each curricular material. Table 4 lists the categories for each characteristic and the number of resources that fit into each category.

Table 4. Independent descriptors of ERC-reviewed, engineering-related science and technology curriculum materials

Grade Level	Frequency
K-2	9
3-5	16
6-8	19

Public. Year	Frequency
1995-1997	7
1998-2000	9
2001-2004	28

Duration	Frequency
1-4.5 weeks	15
5-12 weeks	20
13-26 weeks	9

Author/Series	Frequency	Author/Series	Frequency
FOSS	10	City Tech	5
STC	7	SAE	3
After School	1	IMaST	9
GEMS	1	Indep. Text	8

The first characteristic is intended grade level audience; the three categories are K-2, 3-5, and 6-8. The second characteristic is year of publication, which also has three categories: 1995-1997, 1998-2000, and 2001-2004 (these divisions were chosen because 2001 was the year when Massachusetts established engineering/technology curriculum frameworks). For the characteristic of module duration, the categories are 1-4.5 weeks, 5-12 weeks, and 13-36 weeks. The fourth characteristic is the author or curricular series of the resource (for example, one curricular series is the "Full Option Science System" from Lawrence Hall of Science). There are eight categories of curricular series for the 44 resources in the sample set; these categories include seven actual series titles and one additional category for the independent textbooks that are not part of an author's series.

This portion of the results section describes the Analysis of Variance tests for the four separate independent variables of grade level, publication year, duration, and author/series. The ANOVA test results indicate whether differences in evaluative parameters are due to differences *within* categories or differences *between* categories.

Differences between grade level groups – ANOVA tests with the grade level group as the independent variable were used to explore what grade level audience predicts about the materials reviewed by the ERC. Table 5 and Figure 1 illustrate the ANOVA results for grade level groups. There are statistical differences across the grade level groups for the parameters of usability score, educator support score, total percentage of national standards and state frameworks met, and the percentage of paper & pencil assessments. The usability score for grade 6-8 materials averages 0.68 points higher than the usability score for grade 3-5 materials (significant at the 0.05 level). Moreover, grade 6-8 materials meet 21% and 26% more national standards than grade 3-5 and grade K-2 materials, respectively (statistically significant at the 0.05 level). Roughly 40% more of the grade 6-8 assessments use paper & pencil than do the grade 3-5 and grade K-2 assessments (also significant at level of 0.05).

Differences between publication year groups – ANOVA tests with the publication year category as the independent variable were used to explore whether science and technology curricula included in the ERC have changed systematically over time. Table 6 and Figure 2 illustrate the ANOVA results for publication year. Few evaluative parameters appear to be correlated with year of publication. However, statistically significant differences do exist for educator support score, total percentage of state frameworks met, and percent of paper and pencil assessments. More recently published materials tend to have higher educator support scores; materials from 2001-2004 average 0.86 points higher than materials from 1995-1997 (statistically significant at 0.05 level) and 0.40 points higher than materials from 1998-2000 (not significant).

Differences between module duration groups – To investigate whether the instructional duration of a module can predict its evaluation results, ANOVA tests were executed with the module duration as the independent variable. Table 7 and Figure 3 illustrate the ANOVA results for module duration. As expected, the total percentage of national standards and state frameworks met by a module increases significantly with the module's duration. Conversely, the percent of standards and frameworks met *per week* significantly *decreases* as the module's duration increases.

Differences between author/curricular series groups – Finally, to explore how resources by different authors or from different curricular series compare to each other, ANOVA tests were carried out with the author/series as the independent variable. Table 8 and Figure 4 illustrate these differences. The modules from the SAE series average at least 1.2 points lower on educator support than all of the other author/series (significant differences, at 0.05 level, between SAE and all groups except GEMS). The Independent Textbook category meets a significantly greater total percentage of standards and frameworks than four other categories, but the IMaST and City Technology series meet a significantly greater percentage per week than several other categories. In Figure 4, note that that the total percentage of state frameworks and the weekly percentage of frameworks tend to behave conversely; the same is true for national standards (not shown in Figure 4).

Table 5. ANOVA results for the independent variable of grade level audience. An underscored p-value indicates that there are statistically significant differences between the grade level groups for that metric.

		Grade K-2 (n=9)	Grades 3-5 (n=16)	Grades 6-8 (n=19)	ANOVA p-value
Usability Score	M SD	2.56 (0.59)	2.38 (0.50)	3.05 (0.52)	.0012
Educator Support Score	M SD	3.67 (0.50)	3.12 (0.50)	2.74 (0.65)	.0010
% of National Standards Met	M SD	0.28 (0.18)	0.33 (0.17)	0.54 (0.29)	.0098
% of State Frameworks Met	M SD	0.52 (0.22)	0.29 (0.22)	0.65 (0.24)	.0002
% of National Standards Met Weekly	M SD	0.031 (0.018)	0.072 (0.086)	0.080 (0.081)	.2581
% of State Frameworks Met Weekly	M SD	0.058 (0.023)	0.084 (0.125)	0.111 (0.095)	.4049
% of Assessments That Are Paper & Pencil	M SD	0.02 (0.04)	0.02 (0.02)	0.42 (0.46)	.0006
% of Assessments That Are Portfolio/Journal	M SD	0.52 (0.18)	0.49 (0.19)	0.63 (0.33)	.1174

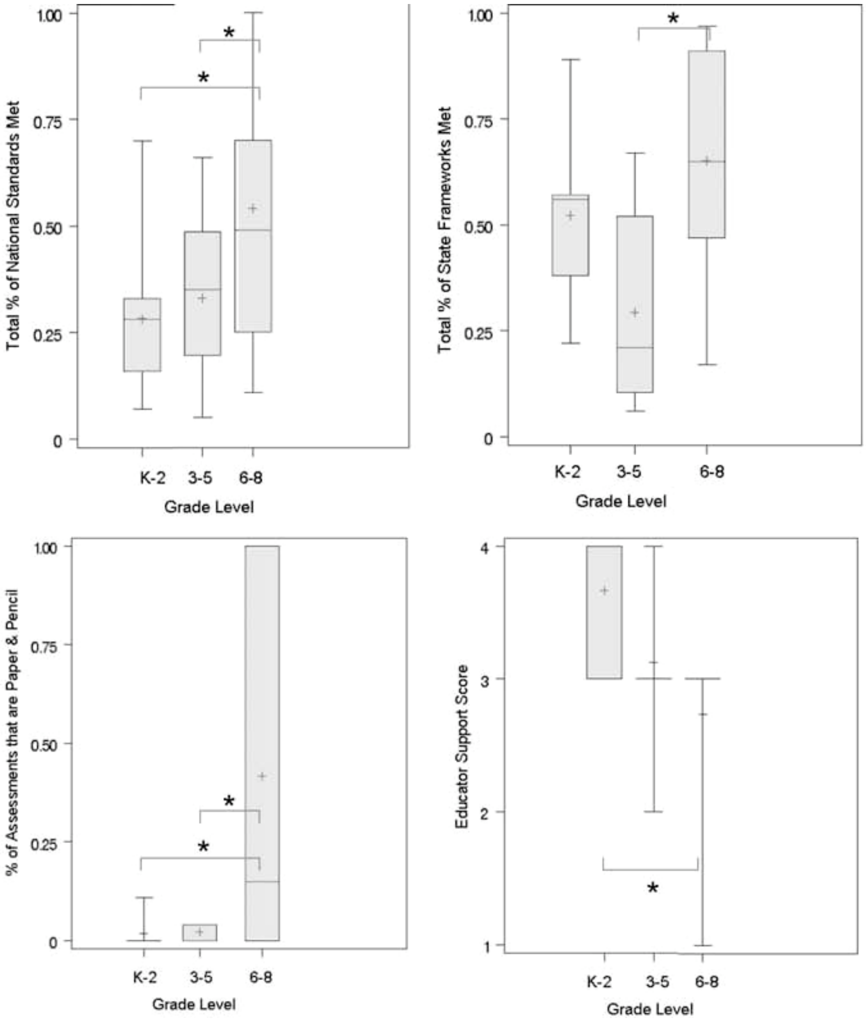

Figure 1. Comparisons across grade levels. Box plots show, as a function of grade level audience, the percentage of national standards met, percentage of state frameworks met, proportion of paper & pencil assessments, and educator support score. Crosses indicate group mean, and asterisks and cross-bars indicate which means are significantly different at the 0.05 significance level.

Table 6. ANOVA results for the independent variable of publication year. An underscored p-value indicates that there are statistically significant differences between the year groups for that metric.

		1995-1997 (n=7)	1998-2000 (n=9)	2001-2004 (n=28)	ANOVA p-value
Usability Score	M	2.86	2.56	2.71	.6064
	SD	(0.38)	(0.73)	(0.60)	
Educator Support Score	M	2.43	2.89	3.29	<u>.0038</u>
	SD	(0.97)	(0.33)	(0.53)	
% of National Standards Met	M	0.61	0.43	0.37	.0643
	SD	(0.33)	(0.23)	(0.23)	
% of State Frameworks Met	M	0.61	0.27	0.54	<u>.0132</u>
	SD	(0.23)	(0.21)	(0.27)	
% of National Standards Met Weekly	M	0.058	0.100	0.059	.3549
	SD	(0.066)	(0.103)	(0.068)	
% of State Frameworks Met Weekly	M	0.063	0.081	0.100	.6589
	SD	(0.060)	(0.098)	(0.107)	
% of Assessments That Are Paper & Pencil	M	0.58	0.04	0.16	<u>.0039</u>
	SD	(0.53)	(0.05)	(0.30)	
% of Assessments That Are Portfolio/Journal	M	0.72	0.51	0.51	.1458
	SD	(0.47)	(0.26)	(0.19)	

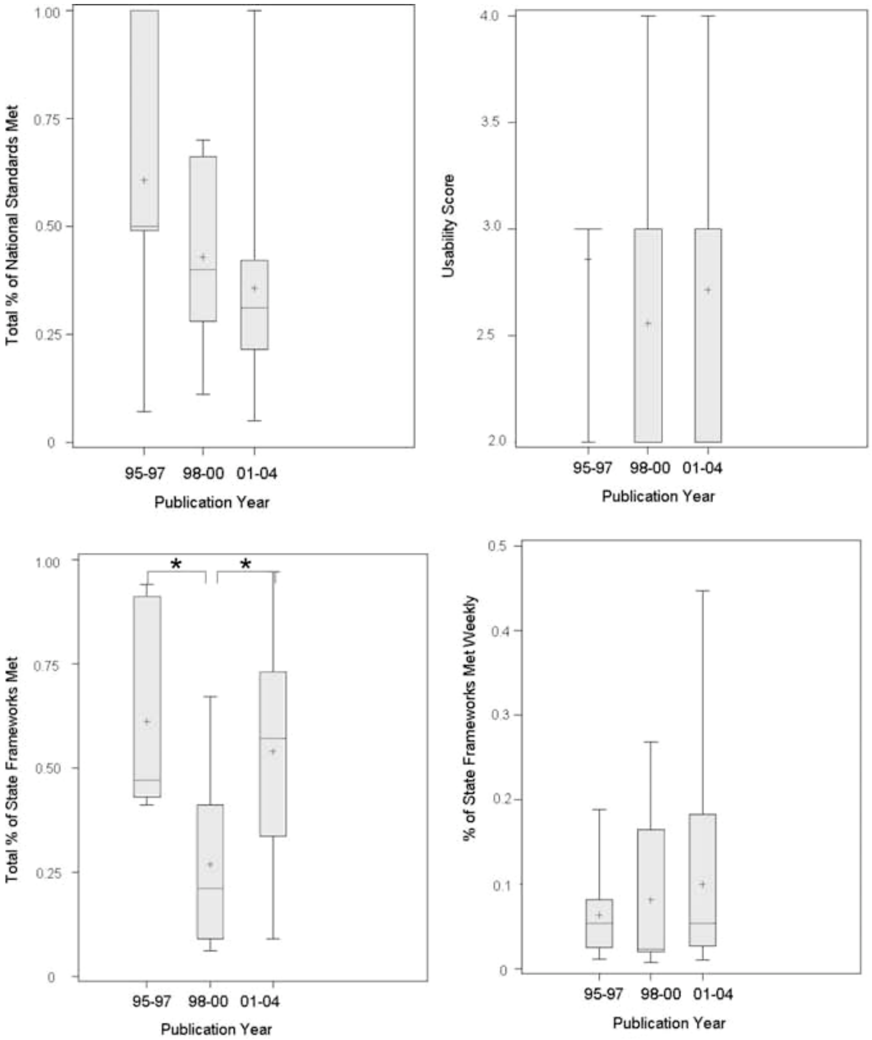

Figure 2. Comparisons across publication year groupings. Box plots show, as a function of publication year, the percentage of national standards met, usability score, total percentage of state frameworks met, and percentage of state frameworks met per week. Crosses indicate group mean, and asterisks indicate which means are significantly different at the 0.05 significance level.

Table 7. ANOVA results for the independent variable of module duration. An underscored p-value indicates that there are statistically significant differences between the duration groups for that metric.

		1 to 4.5 weeks (n=15)	5 to 12 weeks (n=20)	13 to 36 weeks (n=9)	ANOVA p-value
Usability Score	M SD	3.07 (0.59)	2.45 (0.51)	2.67 (0.50)	.0068
Educator Support Score	M SD	3.13 (0.35)	3.05 (0.88)	3.00 (0.50)	.8846
% of National Standards Met	M SD	0.33 (0.20)	0.34 (0.18)	0.71 (0.28)	<.0001
% of State Frameworks Met	M SD	0.46 (0.19)	0.37 (0.24)	0.82 (0.20)	<.0001
% of National Standards Met Weekly	M SD	0.136 (0.096)	0.038 (0.020)	0.020 (0.008)	<.0001
% of State Frameworks Met Weekly	M SD	0.194 (0.105)	0.042 (0.027)	0.023 (0.006)	<.0001
% of Assessments That Are Paper & Pencil	M SD	0.06 (0.07)	0.12 (0.30)	.057 (0.52)	.0008
% of Assessments That Are Portfolio/Journal	M SD	0.63 (0.17)	0.46 (0.21)	0.57 (0.45)	.2060

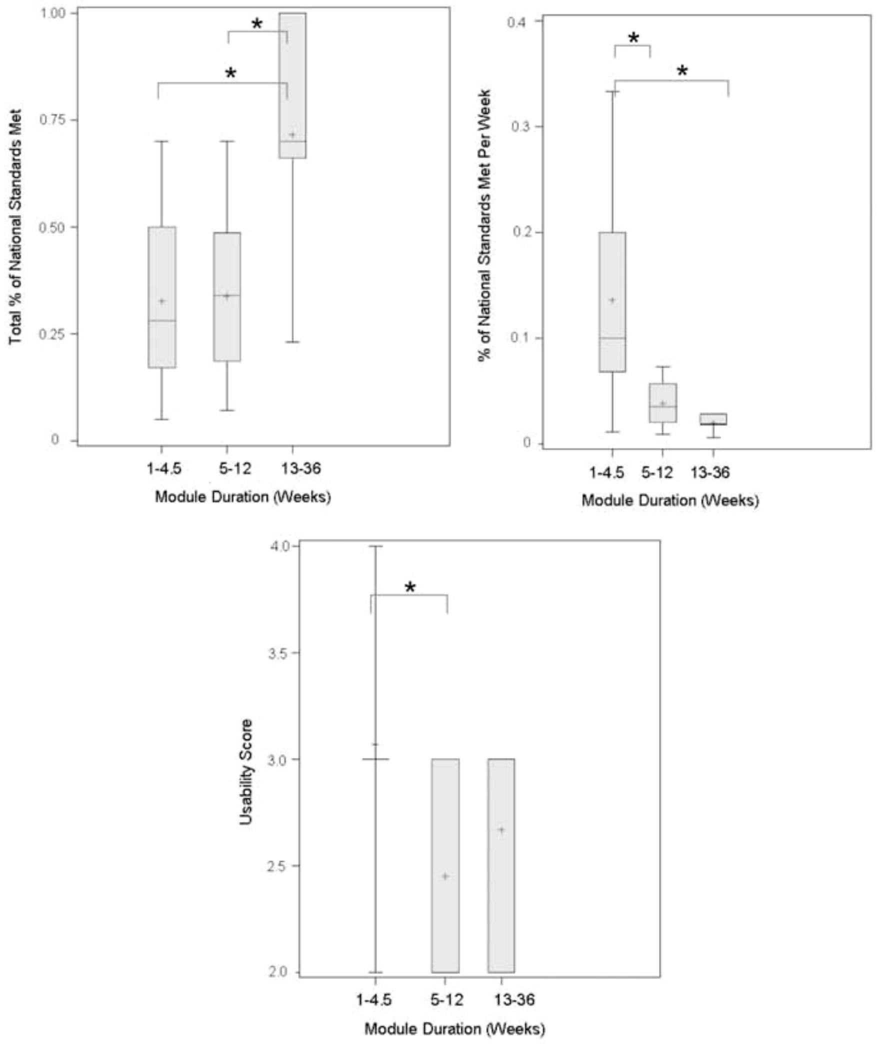

Figure 3. Comparisons across module durations. Box plots show, as a function of duration, the total percentage of national standards met, percentage of standards met per week, and usability score. Crosses indicate group mean, and asterisks indicate which means are significantly different at the 0.05 significance level.

Table 8. ANOVA results with author/series as the independent variable. An underscored p-value indicates that there are statistically significant differences between the author/series groups for that metric.

		FOSS (n=10)	**STC (n=7)**	**After Schl. (n=1)**	**GEMS (n=1)**	**City Tech (n=5)**	**SAE (n=3)**	**IMaST (n=9)**	**Indep. Text (n=8)**	**ANOVA p-value**
Usability Score	M SD	2.30 (0.48)	2.43 (0.53)	2.00	2.00	2.80 (0.45)	3.00 (0.00)	3.33 (0.50)	2.75 (0.46)	.0012
Educator Support Score	M SD	3.20 (0.63)	3.43 (0.53)	4.00	3.00	3.40 (0.55)	1.67 (1.15)	3.00 (0.00)	2.88 (0.35)	.0012
% of National Standards Met	M SD	0.30 (0.18)	0.38 (0.16)	0.23	0.5	0.27 (0.18)	0.35 (0.24)	0.34 (0.22)	0.78 (0.23)	.0006
% of State Frameworks Met	M SD	0.24 (0.16)	0.50 (0.29)	0.57	0.47	0.41 (0.26)	0.52 (0.12)	0.49 (0.16)	0.85 (0.19)	.0001
% of National Standards Met Weekly	M SD	0.038 (0.023)	0.042 (0.017)	0.006	0.200	0.112 (0.133)	0.044 (0.030)	0.137 (0.086)	0.022 (0.007)	.0026
% of State Frameworks Met Weekly	M SD	0.028 (0.017)	0.055 (0.031)	0.016	0.188	0.189 (0.178)	0.065 (0.014)	0.197 (0.063)	0.024 (0.005)	<.0001
% of Assessments Paper&Pencil	M SD	0.03 (0.03)	0.02 (0.03)	0	0.04	0.008 (0.02)	0.67 (0.58)	0.09 (0.07)	0.64 (0.50)	<.0001
% of Assessments Portfol/Journl	M SD	0.43 (0.16)	0.48 (0.16)	0	0.42	0.64 (0.15)	0.53 (0.45)	0.64 (0.19)	0.65 (0.43)	.2264

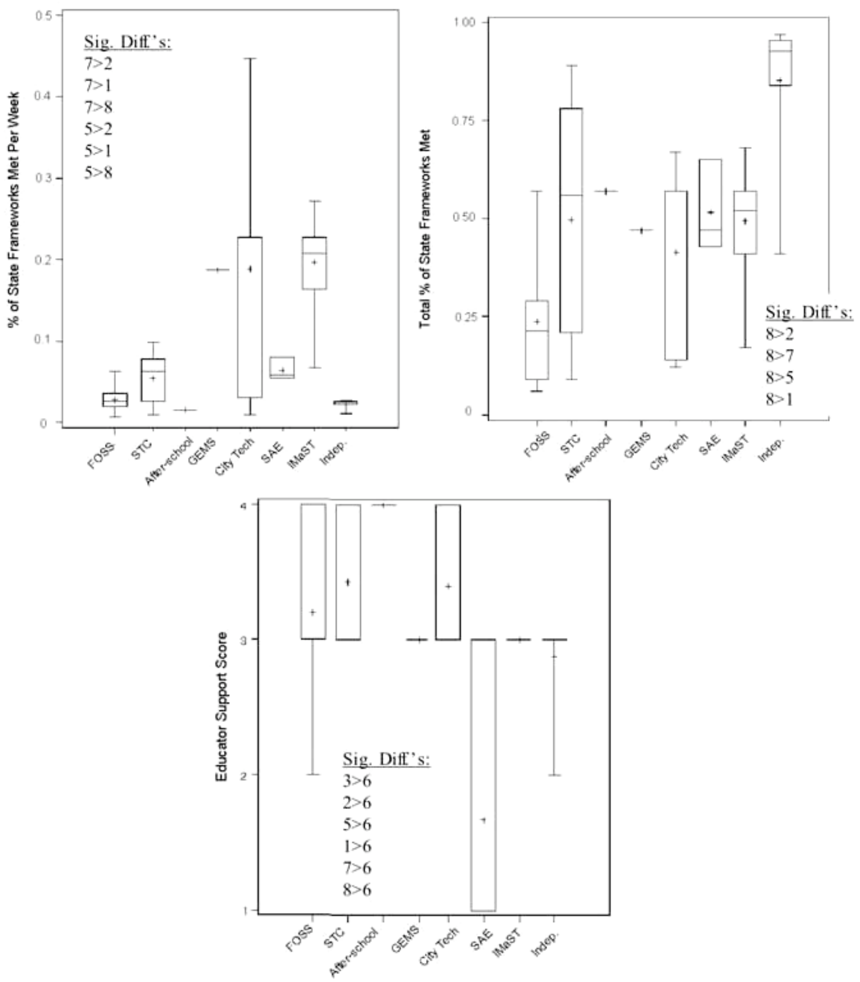

Figure 4. Comparisons across author/series groups. Box plots show total percentage of state frameworks met, percentage of frameworks met per week, and educator support score, as a function of author or curricular series. Crosses indicate group mean, and asterisks indicate which means are significantly different at the 0.05 level.

3.2 Coverage of Specific Standards and Frameworks

The second set of results from this study reveals the frequency with which specific national technology standards and state engineering/technology frameworks are addressed by the ERC-reviewed materials. For the K-2, 3-5, and 6-8 grade levels combined, there are a total of 187 national technology standards and 50 Massachusetts frameworks. The ITEA divides the national standards into 20 different themes, and Massachusetts divides the state frameworks into 11 different themes. Figures 2 and 3 display the average frequency with which the standards or frameworks in each theme are addressed by the ERC-reviewed science and technology curricula. The national standard themes with the least coverage are medical technology, agricultural technology, and transportation technology. Many of the individual standards *within* these themes are not addressed by any of the ERC materials (for details on the coverage of each of the 237 standards/frameworks, see Appendix B). The state framework themes with the least coverage are simple machines at the K-2 level, construction technology at the 6-8 level, and bioengineering technology at the 6-8 level.

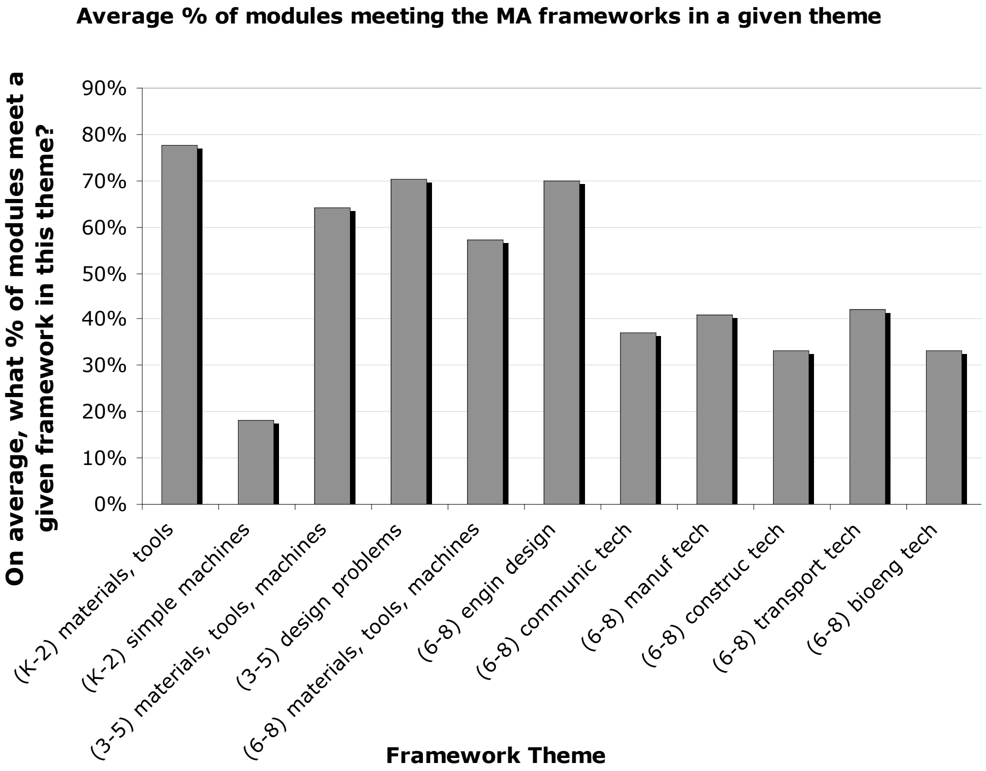

Figure 5. On average, the percentage of grade-appropriate modules that meet the frameworks in each of the major themes of the Massachusetts curriculum frameworks for engineering/technology. An example interpretation of the bar heights follows: for a typical K-2 framework related to simple machines, about 20% of K-2 modules address the framework.

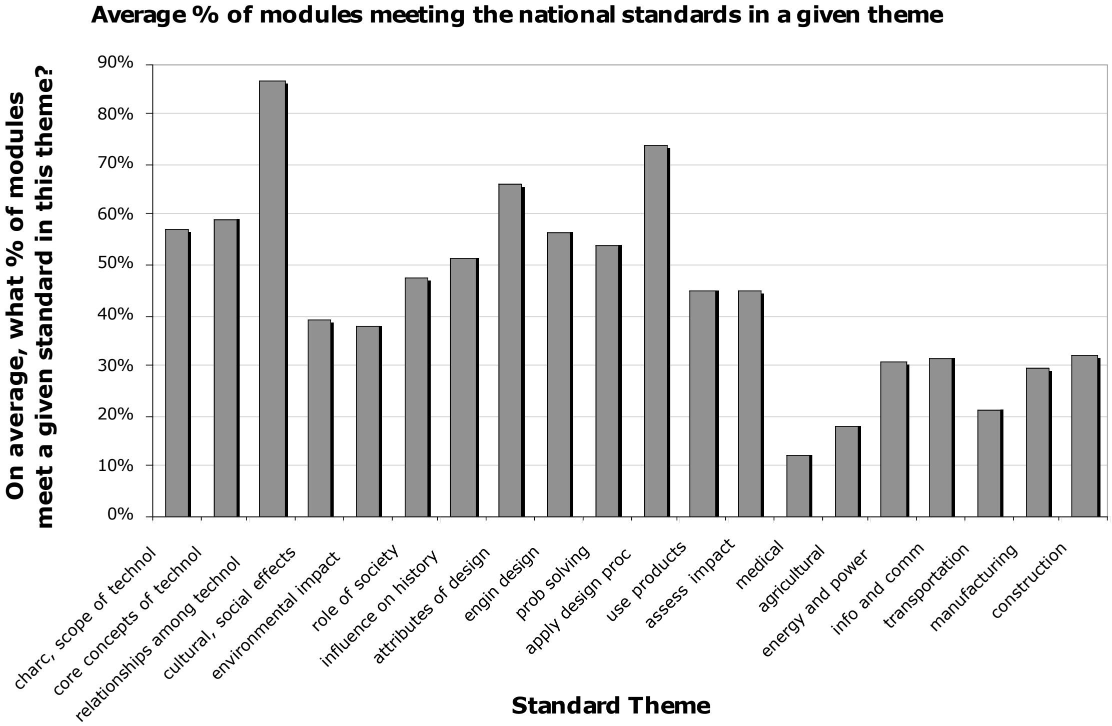

Figure 6. On average, the percentage of grade-appropriate modules that address the content in each of the major themes of the national standards for technological literacy. An example interpretation of the bar heights follows: for a typical standard related to medical technology, about 15% of grade-appropriate modules address the standard.

4. CONCLUSIONS

4.1 Conclusions from Summary Statistics of Evaluation Criteria

The first set of conclusions is drawn from the summary descriptive statistics for the overall group of materials reviewed by the ERC. By examining the averages of the evaluation criteria, we can consider the general usefulness of the ERC-reviewed science and technology curricula for K-8 engineering education. The ERC resources exhibit both strengths and weaknesses.

One strength of the ERC-reviewed educational resources is that they address content at a fairly rapid pace of 7- 9% of standards per week. This pace, if continued for an entire academic year, would surely allow teachers to meet 100% of content standards. Another strength is that as a group, the modules offer a fairly evenly distributed variety of recipe, guided, and open-ended classroom activities. Teachers should be able to find lessons with the appropriate level of scaffolding for their students' needs. A third strength of the modules is the high proportion of assessments that are based on expressive and creative student work, including portfolios, journals, performances, and open-ended assignments.

On the other hand, the engineering-related resources reviewed by the ERC might be perceived as weak in several areas. First, the mean usability score of the modules is 2.7 out of 4. This value implies that modules have room to improve on cost and availability of supplies, time required for set-up, and directions for classroom management. Another potential weakness is that very few modules employ interviews and presentations as assessment methods. Because presentation skills are crucial for practitioners of engineering design, educators may wish to provide their students with more exposure to these tasks. Similarly, redesign activities are not incorporated into very many modules. Curriculum developers might interpret this result as an area for future projects; the process of redesigning an artifact is often an effective way for students to learn how a technology works and at the same time experience the design process. Another infrequently-used pedagogical technique is the warm-up design activity, which might be important for students who are largely unfamiliar with engineering design projects. Finally, not many of the K-2 and 3-5 materials provide paper & pencil assessments, which educators often desire for their ease of grading.

The results of the ANOVA comparisons across independent groups of materials help to answer the question "Are the results of a resource's evaluation correlated with any specific characteristics?" The ANOVA tests suggest that differences between curriculum materials can predict substantial differences in curriculum evaluation results. Based on evidence from the comparisons across groups, I suggest the following set of general "rules" for educators who are making decisions about K-8 engineering curricula and who are concerned with the issues of teacher support, usability, standards and frameworks coverage, and activity and assessment type.

- **Educator Support -** Materials for younger grade levels tend to provide more adequate educator support than materials for middle school, by almost 1 full point out of the 4 possible. Perhaps authors assume that primary teachers have the least background knowledge in engineering and technology. Teachers of older students who require background information on a new topic may find it helpful to consult the teacher's guide for younger grade levels.
- **Usability -** Materials for middle school students tend to be slightly more usable than materials for primary students. This result suggests that materials for older grade levels tend to provide clearer directions for classroom management, cost less, or require less set-up time.
- **Standards and Framework Coverage –**
    - Materials for grades 6-8 cover the most content standards overall, but this dominance in total percentage of standards covered is likely because eight out of the 19 grade 6-8 materials are yearlong textbooks. More important than *total* standards coverage is that grade 6-8 materials also cover the most content for a given amount of time. In other words, the mean percentage of national standards and state frameworks met *per week* is highest for the grade 6-8 materials. This result seems to suggest that materials are developmentally appropriate, as 6th to 8th grade students can handle new concepts at a faster pace than younger students.
    - More recently published materials do not necessarily cover a greater percentage of standards than older materials. Teachers should not assume that the materials published after the establishment of the Massachusetts engineering/technology frameworks address the frameworks more adequately.
    - As expected, materials with longer durations meet a greater percentage of state and national standards. However, materials with shorter durations have a much

higher “content density” – they meet a much greater percentage of standards and frameworks *per week* of instruction. Longer modules appear to be less efficient at covering standards and frameworks. This means that a teacher who selects a series of six 2-week modules for his or her class might actually cover more ground than a teacher who selects just one 12-week module.

- **Assessment Type –** K-5 teachers who desire paper & pencil assessments will not find many of them in the ERC-reviewed engineering-related materials. Paper & pencil assessments are much more common in the materials for grades 6-8.

4.2 Conclusions from Analysis of Standards and Frameworks Coverage

As a group, the ERC-reviewed modules seem to excel at addressing engineering process skills and at covering the standards that treat technology and engineering design as broad concepts. Almost all of the modules, at all grade levels, address the themes of relationships between technologies, applying design procedures, the engineering design process, and using materials and tools. The average standards within these themes are addressed by 87%, 74%, 70%, and 70% of the modules, respectively.

If we examine the coverage of specific technologies and specific effects of engineering and technology, we find that individual modules focus on particular technologies or effects rather than addressing a broad range. The particular topics of medical technology, agricultural technology, or transportation technology appear least often in the ERC materials. The average standards within these themes are addressed by 13%, 18%, and 22% of the modules, respectively. There is also relatively little coverage by the ERC materials of the cultural and social effects of technology development, especially at the K-2 and 3-5 levels. The average standard dealing with cultural and social effects is addressed by 39% of the modules, and this percentage decreases with grade level (see Appendix B).

5. DISCUSSION

The findings from this study take off from the starting point of several other databases and reviews of science and technology curricula, including AAAS’s Project 2061 curriculum review and several engineering-lesson-plan websites. Most curriculum reviews, including the Educator Resource Center reviews, apply an evaluation rubric to a number of textbooks, and then users search through the results to find the curriculum most suited to their needs. This study differs from these curriculum reviews because rather than focusing on individual materials, it provides a summary snapshot of the all of the evaluations of engineering-related curricula in one particular database. It summarizes the reviews of all the K-8 science and technology textbooks or teacher’s guides that have been reviewed by the Educator Resource Center at the Museum of Science, Boston, and that are related to engineering in some way. The evaluations that comprise this summary are different from those in the Project 2061 textbook review because they focus on the appropriateness of the materials for teaching about engineering, instead of only science or technology. The ERC’s evaluation criteria are specific to the needs of educators who are trying to address both the content and processes of engineering/technology. The ERC is also different from other online engineering education material depositories because it includes traditionalstyle textbooks, which persist in guiding classroom instruction more frequently than stand-alone engineering lessons from online digital collections.

The main goal of this study was to determine what could be learned from the Educator Resource Center at the Museum of Science, Boston, about the application of K-8 science and technology curricula for engineering education. Both the summary descriptive statistics of the overall group of materials and the analysis of specific standards and frameworks coverage help us understand the usefulness of elementary and middle grade science curriculum for teaching engineering. The 44 modules in the sample set include several of the major curricular series in science and technology textbooks for elementary and middle grades. Therefore, the data set on the coverage of standards and frameworks is an important contribution to the field of engineering education, as it indicates where prominent textbook creators are focusing their attention, and where they are neglecting to pay attention. Curriculum developers and other stakeholders should take note of the themes that are infrequently covered (especially medical and agricultural technology, cultural and social effects) and work to ensure that future curricula address these themes. This understanding is useful for all the stakeholders in the efforts to improve technological literacy and to increase students' awareness of engineering concepts, processes, and careers.

6. LIMITATIONS

As an analysis of engineering educational resources, this study has several key limitations. Most importantly, the 44 modules reviewed by the ERC represent a convenience sample rather than a random sample of the entire population of K-8 textbooks that are somehow related to engineering/technology. The use of a convenience sample precludes generalizations from these results to the set of *all* engineering-related educational resources. Another limitation related to the ERC evaluation criteria is that there is no publicly-available information on the inter-rater reliability for the subjective measures of usability and educator support, nor is there information on the breakdown of the ten specific components that comprise the usability and educator support scores. Consequently, we do not know the precise cause of low or high scores. Finally, the data analysis procedures for this study confront us with challenges. Sifting through ANOVA results and comparisons of group means is a tedious process, and even after the data has compiled, it is difficult to consider all of the data at once at remember multiple relationships between independent characteristics and evaluation parameter values.

These limitations and other shortcomings of the study give rise to several recommendations for future research. Two procedures may help to verify the validity of the ERC reviews. First, actual users of each of the reviewed modules could be interviewed to determine if their experience is as suggested by the module's evaluation. Second, researchers could apply a different set of evaluation criteria to the ERC curricula and compare the rankings derived from those criteria to the rankings derived from ERC criteria. One alternative set of criteria is the list of 20 initial screening questions for curriculum adopters provided in *Curriculum Topic Study* (Keeley, 2005). My final recommendation concerns this study's lack of generalizability. Future work could include a compilation of *all* of the available K-8 textbooks that address engineering/technology standards, and a random sample could then be selected from this entire population.

7. Acknowledgements

All data from the Educator Resource Center at the Museum of Science, Boston, is used with permission. The author wishes to thank Henry Robinson and others at the Educator Resource Center for their willingness to share their work and have their evaluations subjected to data analysis.

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APPENDIX A

Table A. Listing of all 44 curriculum modules compiled this study.

Title	Curricular program or series	Grade	Module duration (weeks)	% National stds met per week	% MA stds met per week
Design It! Projects	After School	3-5	36	1%	2%
Packaging and Other Structures	City Tech	K - 6	1.5	33%	45%
Mapping	City Tech	K - 5	2.5	5%	23%
Signs, Symbols, and Codes	City Tech	3-6	2.5	14%	23%
Designed Environments: Places, Practices, and Plans	City Tech	3-6	12	3%	1%
Mechanisms and Other Systems	City Tech	K - 6	4.5	1%	3%
Balance and Motion	FOSS	K - 2	8	4%	4%
Air and Weather	FOSS	K - 2	9	2%	6%
Pebbles, Sand, and Silt	FOSS	K - 2	7.5	1%	3%
Water	FOSS	3-5	9	7%	2%
Models and Designs	FOSS	5-6	4	7%	2%
Levers and Pulleys	FOSS	4-6	9	4%	3%
Wood and Paper	FOSS	K-1	10	2%	4%
Ideas and Inventions	FOSS	3-5	9	5%	1%
Magnetism and Electricity	FOSS	3-5	9	4%	1%
Earth Materials	FOSS	3-5	9	2%	2%
Build It! Festival	GEMS	K - 5	2.5	20%	19%
Wellness	IMaST	6-8	2.5	28%	16%
Manufacturing	IMaST	6-8	2.5	14%	27%
Systems	IMaST	6-8	2.5	10%	16%
Waste Management	IMaST	6-8	2.5	28%	19%
Forecasting: Student Text	IMaST	6-8	2.5	7%	7%
Energy Transformations	IMaST	6-8	2.5	4%	27%
Communication Pathways	IMaST	6-8	2.5	13%	23%
Human Settlements	IMaST	6-8	2.5	10%	21%
Animal Habitats	IMaST	6-8	2.5	9%	22%
Technology: Shaping our World	Indep.	6-8	36	2%	3%
Introduction to Technology	Indep.	6-8	36	1%	3%
Technology: Science and Math in Action: Book Two	Indep.	6-8	36	3%	3%
Introduction to Design and Technology	Indep.	8-12	36	2%	1%
Technology: Science and Math in Action: Book One	Indep.	6-8	36	3%	3%
Technology Interactions	Indep.	6-8	36	3%	3%
Technology: Design and Applications	Indep.	6-9	36	2%	3%
Technology in Action	Indep.	6-8	36	2%	2%
A World in Motion: Challenge 1	SAE	4-6	8	1%	5%
A World in Motion: Challenge 2	SAE	6-8	8	6%	8%
A World in Motion: Challenge 3	SAE	7-8	8	6%	6%
Solids and Liquids	STC	K - 2	9	2%	6%
Changes	STC	K-2	10	3%	8%
Balancing and Weighing	STC	K - 2	8	4%	7%
Weather	STC	K - 2	8	4%	10%
Motion and Design	STC	3-5	8	6%	3%
Sound	STC	3-5	9	3%	1%
Soils	STC	K - 2	10	7%	4%

APPENDIX B

Table B. Percentage of modules that meet each individual standard and framework. A complete description of the standard or framework can be found by referencing the listed code in either *Standards for Technological Literacy* or *Massachusetts Curriculum Frameworks.*

State or National?	Std. Code	Topic of Standard	Grade Level	% of Grade-Appropriate Modules Meeting Std
U.S.	14A	medical tech	K to 2	0%
U.S.	14B	medical tech	K to 2	0%
U.S.	14C	medical tech	K to 2	0%
U.S.	14D	medical tech	3 to 5	0%
U.S.	14E	medical tech	3 to 5	0%
U.S.	14F	medical tech	3 to 5	0%
U.S.	15A	agricultural tech	K to 2	0%
U.S.	15B	agricultural tech	K to 2	0%
U.S.	15C	agricultural tech	3 to 5	0%
U.S.	15D	agricultural tech	3 to 5	0%
U.S.	15E	agricultural tech	3 to 5	0%
U.S.	16A	energy and power tech	K to 2	0%
U.S.	16B	energy and power tech	K to 2	0%
U.S.	17B	info and comm tech	K to 2	0%
U.S.	18A	transportation tech	K to 2	0%
U.S.	18B	transportation tech	K to 2	0%
U.S.	18C	transportation tech	K to 2	0%
U.S.	18D	transportation tech	3 to 5	0%
U.S.	18E	transportation tech	3 to 5	0%
U.S.	19E	manufacturing tech	3 to 5	0%
U.S.	20C	construction tech	3 to 5	0%
U.S.	12F	use technological products	3 to 5	7%
U.S.	19C	manufacturing tech	3 to 5	7%
U.S.	19D	manufacturing tech	3 to 5	7%
U.S.	20E	construction tech	3 to 5	7%
U.S.	13D	assess impact	3 to 5	14%
U.S.	16C	energy and power tech	3 to 5	14%
U.S.	16D	energy and power tech	3 to 5	14%
U.S.	17F	info and comm tech	3 to 5	14%
U.S.	17G	info and comm tech	3 to 5	14%
U.S.	20D	construction tech	3 to 5	14%
U.S.	4B	cultural, social effects of techn	3 to 5	14%
U.S.	4C	cultural, social effects of techn	3 to 5	14%
U.S.	5B	environmental impact	3 to 5	14%
U.S.	19A	manufacturing tech	K to 2	15%
U.S.	19B	manufacturing tech	K to 2	15%
U.S.	20A	construction tech	K to 2	15%
U.S.	4A	cultural, social effects of techn	K to 2	15%
MA	2	simple machines	K to 2	18%
MA	2.1	simple machines	K to 2	18%
MA	2.2	simple machines	K to 2	18%

U.S.	15J	agricultural tech	6 to 8	19%
U.S.	12G	use technological products	3 to 5	21%
U.S.	5C	environmental impact	3 to 5	21%
U.S.	12B	use technological products	K to 2	23%
U.S.	12C	use technological products	K to 2	23%
U.S.	17A	info and comm tech	K to 2	23%
U.S.	17C	info and comm tech	K to 2	23%
U.S.	2A	core concepts of techn	K to 2	23%
U.S.	7A	influence on history	K to 2	23%
MA	5.1	construction tech	6 to 8	24%
U.S.	14H	medical tech	6 to 8	25%
MA	2.4	design problems	3 to 5	29%
MA	3.4	communication tech	6 to 8	29%
MA	6.1	transportation tech	6 to 8	29%
MA	6.2	transportation tech	6 to 8	29%
MA	7.1	bioengineering tech	6 to 8	29%
U.S.	12D	use technological products	3 to 5	29%
U.S.	13C	assess impact	3 to 5	29%
U.S.	13E	assess impact	3 to 5	29%
U.S.	17D	info and comm tech	3 to 5	29%
U.S.	2F	core concepts of techn	3 to 5	29%
U.S.	2K	core concepts of techn	3 to 5	29%
U.S.	11A	apply design procedures	K to 2	31%
U.S.	14G	medical tech	6 to 8	31%
U.S.	14I	medical tech	6 to 8	31%
U.S.	5A	environmental impact	K to 2	31%
U.S.	9A	engineering design	K to 2	31%
U.S.	9B	engineering design	K to 2	31%
MA	3.1	communication tech	6 to 8	33%
MA	4.1	manufacturing tech	6 to 8	33%
MA	5.2	construction tech	6 to 8	33%
MA	5.3	construction tech	6 to 8	33%
MA	7	bioengineering tech	6 to 8	33%
U.S.	12E	use technological products	3 to 5	36%
U.S.	17E	info and comm tech	3 to 5	36%
U.S.	1C	charcac & scope of techn	3 to 5	36%
U.S.	2H	core concepts of techn	3 to 5	36%
MA	3.2	communication tech	6 to 8	38%
MA	4	manufacturing tech	6 to 8	38%
MA	4.2	manufacturing tech	6 to 8	38%
MA	5	construction tech	6 to 8	38%
MA	5.4	construction tech	6 to 8	38%
MA	7.2	bioengineering tech	6 to 8	38%
U.S.	10B	problem solving	K to 2	38%
U.S.	11C	apply design procedures	K to 2	38%
U.S.	14J	medical tech	6 to 8	38%
U.S.	15G	agricultural tech	6 to 8	38%
U.S.	15I	agricultural tech	6 to 8	38%
U.S.	16I	energy and power tech	6 to 8	38%

U.S.	18H	transportation tech	6 to 8	38%
U.S.	18I	transportation tech	6 to 8	38%
U.S.	19G	manufacturing tech	6 to 8	38%
U.S.	1I	charcac & scope of techn	6 to 8	38%
U.S.	6F	role of society	6 to 8	38%
U.S.	6G	role of society	6 to 8	38%
MA	3	communication tech	6 to 8	43%
MA	3.3	communication tech	6 to 8	43%
MA	4.4	manufacturing tech	6 to 8	43%
MA	6	transportation tech	6 to 8	43%
U.S.	10E	problem solving	3 to 5	43%
U.S.	1E	charcac & scope of techn	3 to 5	43%
U.S.	2G	core concepts of techn	3 to 5	43%
U.S.	15F	agricultural tech	6 to 8	44%
U.S.	15H	agricultural tech	6 to 8	44%
U.S.	16H	energy and power tech	6 to 8	44%
U.S.	17I	info and comm tech	6 to 8	44%
U.S.	19J	manufacturing tech	6 to 8	44%
U.S.	20H	construction tech	6 to 8	44%
U.S.	5E	environmental impact	6 to 8	44%
U.S.	6D	role of society	6 to 8	44%
U.S.	6E	role of society	6 to 8	44%
U.S.	10A	problem solving	K to 2	46%
U.S.	11B	apply design procedures	K to 2	46%
U.S.	20B	construction tech	K to 2	46%
U.S.	2B	core concepts of techn	K to 2	46%
U.S.	2C	core concepts of techn	K to 2	46%
U.S.	2E	core concepts of techn	K to 2	46%
MA	6.4	transportation tech	6 to 8	48%
MA	1.3	materials, tools, machines	3 to 5	50%
U.S.	10C	problem solving	3 to 5	50%
U.S.	10D	problem solving	3 to 5	50%
U.S.	13G	assess impact	6 to 8	50%
U.S.	19F	manufacturing tech	6 to 8	50%
U.S.	19H	manufacturing tech	6 to 8	50%
U.S.	19I	manufacturing tech	6 to 8	50%
U.S.	19K	manufacturing tech	6 to 8	50%
U.S.	20G	construction tech	6 to 8	50%
U.S.	2L	core concepts of techn	3 to 5	50%
U.S.	5F	environmental impact	6 to 8	50%
U.S.	7B	influence on history	3 to 5	50%
U.S.	9F	engineering design	6 to 8	50%
U.S.	9G	engineering design	6 to 8	50%
U.S.	9H	engineering design	6 to 8	50%
MA	1.1	materials, tools, machines	6 to 8	52%
MA	2.3	engineering design	6 to 8	52%
MA	2.5	engineering design	6 to 8	52%
MA	2.6	engineering design	6 to 8	52%
MA	4.3	manufacturing tech	6 to 8	52%

U.S.	12A	use technological products	K to 2	54%
U.S.	13B	assess impact	K to 2	54%
U.S.	1A	charcac & scope of techn	K to 2	54%
U.S.	2D	core concepts of techn	K to 2	54%
U.S.	6A	role of society	K to 2	54%
U.S.	13F	assess impact	6 to 8	56%
U.S.	13H	assess impact	6 to 8	56%
U.S.	13I	assess impact	6 to 8	56%
U.S.	16E	energy and power tech	6 to 8	56%
U.S.	16F	energy and power tech	6 to 8	56%
U.S.	16G	energy and power tech	6 to 8	56%
U.S.	17H	info and comm tech	6 to 8	56%
U.S.	17J	info and comm tech	6 to 8	56%
U.S.	17K	info and comm tech	6 to 8	56%
U.S.	18G	transportation tech	6 to 8	56%
U.S.	20F	construction tech	6 to 8	56%
U.S.	20I	construction tech	6 to 8	56%
U.S.	4D	cultural, social effects of techn	6 to 8	56%
U.S.	4E	cultural, social effects of techn	6 to 8	56%
U.S.	4G	cultural, social effects of techn	6 to 8	56%
U.S.	7C	influence on history	6 to 8	56%
U.S.	7F	influence on history	6 to 8	56%
U.S.	8E	attributes of design	6 to 8	56%
U.S.	8F	attributes of design	6 to 8	56%
U.S.	8G	attributes of design	6 to 8	56%
MA	1	materials, tools, machines	3 to 5	57%
MA	1	materials, tools, machines	6 to 8	57%
MA	1.3	materials, tools, machines	6 to 8	57%
U.S.	11D	apply design procedures	3 to 5	57%
U.S.	2I	core concepts of techn	3 to 5	57%
U.S.	2J	core concepts of techn	3 to 5	57%
U.S.	3B	relationships among techn	3 to 5	57%
U.S.	6B	role of society	3 to 5	57%
U.S.	6C	role of society	3 to 5	57%
MA	1.2	materials, tools, machines	6 to 8	62%
MA	2.4	engineering design	6 to 8	62%
MA	6.3	transportation tech	6 to 8	62%
U.S.	13A	assess impact	K to 2	62%
U.S.	18F	transportation tech	6 to 8	63%
U.S.	1F	charcac & scope of techn	6 to 8	63%
U.S.	1G	charcac & scope of techn	6 to 8	63%
U.S.	1H	charcac & scope of techn	6 to 8	63%
U.S.	2O	core concepts of techn	6 to 8	63%
U.S.	2U	core concepts of techn	6 to 8	63%
U.S.	4F	cultural, social effects of techn	6 to 8	63%
U.S.	7D	influence on history	6 to 8	63%
U.S.	7E	influence on history	6 to 8	63%
MA	1.1	materials, tools, machines	3 to 5	64%
U.S.	10F	problem solving	6 to 8	69%

U.S.	10G	problem solving	6 to 8	69%
U.S.	10H	problem solving	6 to 8	69%
U.S.	2V	core concepts of techn	6 to 8	69%
U.S.	5D	environmental impact	6 to 8	69%
U.S.	8A	attributes of design	K to 2	69%
MA	2	engineering design	6 to 8	71%
MA	2.2	design problems	3 to 5	71%
U.S.	11G	apply design procedures	3 to 5	71%
U.S.	1D	charcac & scope of techn	3 to 5	71%
U.S.	8C	attributes of design	3 to 5	71%
U.S.	9E	engineering design	3 to 5	71%
MA	1	materials, tools	K to 2	73%
MA	1.2	materials, tools	K to 2	73%
U.S.	12I	use technological products	6 to 8	75%
U.S.	12J	use technological products	6 to 8	75%
U.S.	12K	use technological products	6 to 8	75%
U.S.	2Q	core concepts of techn	6 to 8	75%
U.S.	8B	attributes of design	K to 2	77%
MA	2.1	design problems	3 to 5	79%
U.S.	3C	relationships among techn	3 to 5	79%
U.S.	8D	attributes of design	3 to 5	79%
U.S.	9C	engineering design	3 to 5	79%
U.S.	12H	use technological products	6 to 8	81%
U.S.	2R	core concepts of techn	6 to 8	81%
MA	1.1	materials, tools	K to 2	82%
MA	1.3	materials, tools	K to 2	82%
U.S.	1B	charcac & scope of techn	K to 2	85%
U.S.	3A	relationships among techn	K to 2	85%
MA	1.2	materials, tools, machines	3 to 5	86%
MA	2	materials, tools, machines	3 to 5	86%
MA	2.3	design problems	3 to 5	86%
U.S.	11F	apply design procedures	3 to 5	86%
U.S.	11L	apply design procedures	6 to 8	88%
U.S.	2M	core concepts of techn	6 to 8	88%
U.S.	2N	core concepts of techn	6 to 8	88%
U.S.	2P	core concepts of techn	6 to 8	88%
U.S.	2S	core concepts of techn	6 to 8	88%
U.S.	2T	core concepts of techn	6 to 8	88%
U.S.	11E	apply design procedures	3 to 5	93%
U.S.	9D	engineering design	3 to 5	93%
U.S.	11H	apply design procedures	6 to 8	94%
U.S.	11I	apply design procedures	6 to 8	94%
U.S.	11J	apply design procedures	6 to 8	94%
U.S.	11K	apply design procedures	6 to 8	94%
MA	2.1	engineering design	6 to 8	100%
MA	2.2	engineering design	6 to 8	100%
U.S.	3D	relationships among techn	6 to 8	100%
U.S.	3E	relationships among techn	6 to 8	100%
U.S.	3F	relationships among techn	6 to 8	100%