Engineering Analytic Principles and Predictive Computational Skills for K-12 Students:

Statistics on High School Age-Possible Capstone Engineering Design and Research Topics to Engineering and Technology Educators and Curriculum Developers

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Introduction

In the most recent decade, middle and high schools across the United States have tried to incorporate engineering design into traditional technology curriculum, with various degrees of success; however, "the fragmented focus and lack of a clear curriculum framework" had been "detrimental to the potential of the field and have hindered efforts aimed at achieving the stated goals of technological literacy for all students" (Smith and Wicklein, 2007, pp. 2-3). A report issued on September 8, 2009, by the Committee on K-12 Engineering Education established by the National Academy of Engineering and the National Research Council, titled *Engineering in K-12 Education: Understanding the Status and Improving the Prospects* (2009), confirmed the existence of similar problems, such as the "absence of a clear description of which engineering knowledge, skills, and habits of mind are most important, how they relate to and build on one another, and how and when (i.e., at what age) they should be introduced to students" (pp. 7-8; p. 151). K-12 engineering curriculum in the United States remains skeletal so far; its main focus is on generic design process using a "trial-and-error" approach; and the coverage of analytic and predictive knowledge contents is generally in an "ad hoc" fashion and not sequentially structured. In response to the above problems, many scholars have voiced their points of view. Hacker (2011) pointed out that "trial-and-error problem solving takes substantial classroom time, and often does not allow teachers and students to focus on the most important learning goals." Lewis (2007, pp. 846-848) discussed the need to: (a). establish a "codified body of knowledge that can be ordered and articulated across the grades" instead of short term efforts focused on a particular topic or unit, and (b). make engineering education a coherent system with the creation of content standards for the subject area, in line with science and technology education.

High School Age-possible Engineering Topics
(Capstone Engineering Design and Research)

Research Questions and Practical Conceptual Framework

The above evaluation of the current status of K-12 engineering education in the United States could lead to these questions: (1). "How could we determine what engineering analytic principles and predictive skills from what subject should be taught to students at what Grade in the K-12 curriculum, in a rational and scientific way?" (2). "How could we make sure that what students learned from high school engineering curriculum could be transferred to university programs?" Based on the way engineering curriculum has been historically developed, I have constructed a practical conceptual framework to answer the above two questions. If we read any typical information sheet for university level undergraduate engineering program, we will see that the courses are organized in a sequence based on the fulfillment of pre-requisites in mathematics, physics, chemistry, technology and previous engineering courses; and these pre-requisites are usually listed in course descriptions. Therefore, we could hypothesize that the same principles used historically in the development of curricular structure in university undergraduate engineering programs could apply to the selection of K-12 age-possible engineering analytic principles and predictive skills for any particular Grade, and for any particular subject of engineering. In addition, based on the fact that university undergraduate engineering textbooks, especially those used in foundation courses (such as statics, dynamics, strength of materials, engineering economics, etc.), all contain portions that are based on pre-calculus mathematics and scientific principles which are usually covered in K-12 mathematics and science courses, we could also hypothesize that these pre-calculus portions of engineering topics could possibly be taught at various Grade levels, provided that the pre-requisite pre-calculus mathematics and science principles have been covered in previous Grade levels (or in some cases, taught as special topics); and the coverage of such pre-requisites are usually mandated by the performance standards in mathematics and science established by any particular state. This conceptual framework has been used as a practical tool for the initial determination of 9th grade age-possible statics and fluid mechanics topics. The step-by-step procedure or the "ideal" procedure (Locke, 2009a, pp. 26-27) includes the following (*Figure 1*): (1) <u>selection of data source</u> (selection of popular university undergraduate engineering textbooks and other instructional and learning materials); (2) <u>analysis of data source</u> (careful reading of every paragraph in the body text as well as relevant computational formulas to find and record the pre-requisite mathematics skills and scientific principles needed for each topic; (3) <u>comparison</u> (between the recorded mathematics and science pre-requisites, and my interpretation of the mandates of the Performance Standards for Mathematics and Sciences of the Department of Education of a selected state, in this case, the State of Georgia, to determine the Grade level for the age-possible inclusion of the topics). I selected the State of Georgia's Standards as a reference for the research because (1) the University of Georgia, my alma mater, gave me the opportunity to study the subject of K-12 engineering education and (2) many professors at the College of Education and the College of Agricultural and Environmental Sciences (Department of Biological and Agricultural Engineering) offered me valuable advice and criticism. Due to the fact that the variations among the K-12 mathematics and science performance standards of the 50 states are not substantial, the outcomes of the research should apply to other states with some reasonable adaptations.

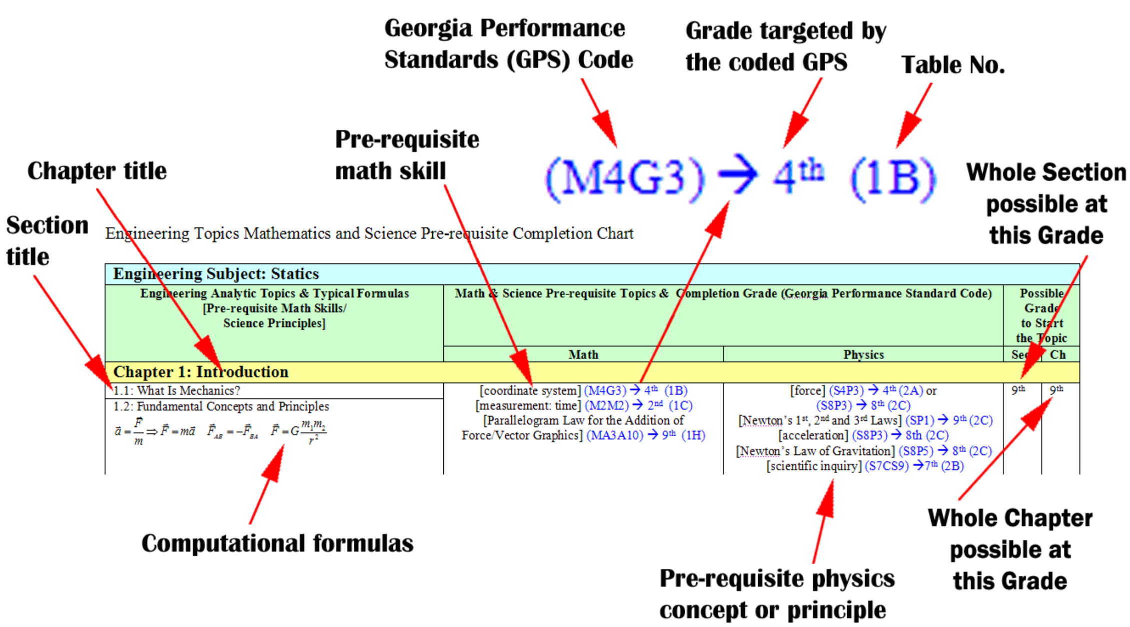

Figure 1. The original research data table used to initially determine high school 9th Grade age-possible statics topics.

After completing all lower-division undergraduate mechanical engineering courses plus two upper-division ones, and conducting a careful and fairly thorough examination of many other college-level engineering textbooks, I have made the conclusion that all engineering textbooks include the following major elements:

(1) **Descriptive and informational:** Paragraphs, data tables, charts, graphs, illustrations and photos that explain natural phenomena, scientific principles, properties of materials, behaviors of structures and systems, in "plain English," without going into the details of analytic and predictive computations using formulas based on mathematics skills.

(2) **Analytic and predictive:** Mathematics-based formulas, including those used in pre-requisite physics and chemistry concepts, principles and analysis, and those used in engineering analysis and design, and step-by-step procedures, including sample problems with solutions, for analyzing problems, predicting outcomes, or designing systems or products; and these mathematics skills could be at either pre-calculus level, i.e., arithmetic, trigonometry, geometry, algebra, or at calculus level, i.e., integration and differentiation.

In terms of the relative amount of each of the above major elements in the overall composition of the content of the textbooks, all sets of college-level engineering textbooks used in any particular course or subject could be classified into three major categories; i.e., (1) Mixture of Pre-calculus and Calculus, (2) Heavily Pre-calculus, and (3) Heavily Descriptive and Informational. It takes different amounts of time and efforts to examine different sets of textbooks under different categories in order to tentatively determine and select K12 age-possible engineering content knowledge and skills, including descriptive and informational materials, analytic and predictive computational formulas and step-by-step problem solving procedures; and the procedure of this examination include (a) interpretation of the mandates of the Performance Standards for Mathematics and Sciences of the Department of Education of a selected state, in this case, the State of Georgia, to create a coded list of items of mathematics, physics and chemistry concepts and skills, such as *M4G3→4th Grade (1B)* shown in *Figure 1*, from the original online government document, to be used for comparison with the mathematics, physics and chemistry concepts and skills found from the relevant textbooks; (b) paragraph-by-paragraph or page-by-page examination of the selected textbooks for the extraction and documentation of the mathematics, physics and chemistry concepts and skills needed to understand the content and to solve homework problems; and (c) comparison between the interpreted, itemized and coded lists of Performance Standards and the items extracted from the textbooks, to tentatively determine and select sections and chapters in the textbooks that could be K12 age-possible. In the United States, we have a very decentralized management structure for the publication and adaptation of textbooks; and this is especially true for textbooks used in the institutions of higher education where professors usually select textbooks out of their own choices free from government intervention; for any college courses or subject, we can find several excellent and popular textbooks, all of them cover a majority of similar topics plus a small number of different ones; therefore, to be holistic and comprehensive, at least two of the most popular textbooks will be used, one as the "primary source of data" and the rest as "secondary source of data" and "additional sources of data." The nature of composition of the above-mentioned three major categories of textbooks and the average amount of time it takes for their examination are as follows:

1. **Mixture of Pre-calculus and Calculus:** Textbooks under this category include, for the undergraduate mechanical engineering major, those used in the courses of statics, dynamics, strength of materials, electric machines, mechanical design, aerodynamics, fluid mechanics, electrical circuits, heat transfer, thermodynamics, and others. For these textbooks, calculus and pre-calculus skills are used intermittently throughout substantial portions of most of the chapters. These textbooks are usually voluminous and the numbers of pages range from 600 to 900. Therefore, a thorough investigation of all paragraphs, formulas, and even sample problems in the textbooks, and a very detailed record of all pertinent information in tabular forms is needed to determine and to select K-12 age-possible engineering topics for different grade levels. My research projects on the subjects of statics and fluid mechanics have been completed this way. This procedure is very thorough and time-consuming and for one subject, it takes between 3 to 5 weeks for one textbook (the "primary source of data"), and additional 1 to 2 weeks for another textbook (the "secondary source of data" used to pick up additional K12 age-possible topics); these amounts of time cover careful reading of all chapters, sections, and even appendices and glossaries throughout the entire textbooks, analysis and recording of mathematics, physics and chemistry concepts and skills involved, typing of titles of chapters, sections, formulas, names of pre-requisite items, write-ups of conclusions, as well as a section-by-section review. Typing of titles of chapters, sections, and formulas could take up to one third of the above amounts of time needed for the research. It is the exact or "ideal" procedure advocated in my published Vision Paper.

2. **Heavily Pre-calculus:** Textbooks under this category include those used in the courses of engineering economics, probability and statistics, and others. For these textbooks, the mathematics skills involved in the majority or even the overwhelming majority of chapters and sections are at pre-calculus level; the calculus skills involved in a few sections or chapters are the very beginning ones such as [first integral] and [first derivative]; and the principles and skills related to physics and chemistry are also the very basic ones; therefore, a less time-consuming approach is used to determine and select K12 age-possible engineering topics, by carefully examine each page in the textbooks to record (1) the pre-calculus level mathematics skills as well as physics and chemistry concepts, principles and skills found in all pages; (2) the calculus-level mathematics skills found in some pages, the page numbers where these calculus skills are found, the numbers and names as well as the pages ranges of the sections involving the calculus skills; and (3) result of comparison between the pre-calculus skills as well as physics and chemistry concepts and skills found throughout the textbooks, and the mandates of the Performance Standards for Mathematics and Sciences of the Department of Education of a selected state, in this case, the State of Georgia, to determine the earliest Grade level for the age-possible inclusion of the topics. My research projects on the subjects of engineering economics, probability and statistics, and engineering materials have been completed this way. This procedure is fairly thorough but much less time-consuming because no record of mathematics-based formulas or typing of the names of chapters and sections of the textbooks that involve only pre-calculus mathematics skills is needed, and for one subject, it takes between 5 to 7 days for one textbook (the "primary source of data") and additional 2 to 4 days for another textbook (the "secondary source of data"). These amounts of time cover careful reading of all chapters, sections, and even appendices and glossaries throughout the entire textbooks, analysis and recording of

mathematics, physics and chemistry concepts and skills involved as pre-requisites, typing of page numbers and titles of chapters and sections involving calculus stills as well as numbers of the individual pages involved, write-ups of conclusions, as well as a section-by-section review. It is a convenient and "ad hoc" revision of the "ideal" procedure advocated in my published Vision Paper.

3. **Heavily Descriptive and Informational:** Textbooks under this category include those used in the courses of introduction to science, engineering and technology, ethics and professionalism in engineering, and others. These textbooks involve little or no mathematics skills; their primary goal is to expose students to broad knowledge about engineering, science, technology, as well as their relationship with "other stuff" such as society, ecology, legal system, philosophy, and others. Similar method as the one used for the "Heavily Pre-calculus" textbooks is used here but the amounts of time spent is substantially reduced because, for the "Heavily Descriptive and Informational" textbook, mathematics, physics and chemistry pre-requisites are rarely involved. For one subject, it takes between 1 to 3 days for one textbook (the "primary source of data") and additional 1 to 2 days for another textbook (the "secondary source of data"). These amounts of time cover careful reading of all chapters, sections, and even appendices and glossaries throughout the entire textbooks, analysis and recording of a few mathematics, physics and chemistry concepts and skills involved as pre-requisites, write-ups of conclusions, as well as a section-by-section review. It is a convenient, "ad hoc" and more drastic revision of the "ideal" procedure advocated in my published Vision Paper.

For the particular subject of capstone engineering design and research, the knowledge content covered in the reading of the textbooks selected in this research, classroom lecture, homework assignments and quizzes or examinations are, for all practical purposes, using predictive and computational formulas based on pre-calculus mathematics concepts and skills, and the involvement of concepts and skills in physics and chemistry is minimal and not applicable. In fact, the content of all selected Textbooks 1 through 8 are mostly descriptive and informational. Therefore, for all practical purposes, all pages of the selected Textbooks 1 through 8 used as reference sources have been carefully and thoroughly examined to record the pre-calculus-level mathematics skills, physics and chemistry concepts and skills, as well as calculus level ones with the numbers and names of relevant chapters or sections. An overall analysis of the data so collected has then been conducted to reach a practical conclusion about the selection of K12 age-possible topics from the selected Textbooks 1 through 8.

Sources of Data

Table 1 lists the college-level Textbooks 1 through 8 used for the extraction of analytic and predictive principles and computational formulas related to the subject of capstone engineering design and research.

Table 1. Data Source (Capstone Engineering Design and Research Textbooks)

	Textbooks Examined							
	Textbook 1	**Textbook 2**	**Textbook 3**	**Textbook 4**	**Textbook 5**	**Textbook 6**	**Textbook 7**	**Textbook 8**
Title	Introduction to Engineering Design and Problem Solving, 2nd Edition	Product Design Techniques in Reverse Engineering and New Product Development	Engineering Design	Fundamentals of Engineering Design, 2nd Edition	An Introduction to Mechanical Engineering	The Mechanical Design Process, 3rd Edition	Engineering Success	Technology and the Future, 11th Edition
Authors	Arvid R. Eide, Roland D. Jenison, Lane H. Mashaw, and Larry L. Northup	Kevin Otto and Kristin Wood	Rudolph J. Eggert	Barry Hyman	Jonathan Wickert	David G. Ullman	Peter Schiavone	Albert H. Teich
Publisher	McGraw-Hill Higher Education	Prentice Hall (Pearson Education)	Pearson Prentice Hall	Prentice Hall (Pearson Education)	Thompson Brooks/Cole	McGraw-Hill Higher Education	Prentice Hall	Wadsworth Cengage Learning
Year	2002	2000	2005	2003	2004	2003	1999	2009
ISBN	0-07-240221-0	0-13-021271-7	0-13-143358-X	0-13-046712-X	0-534-39132-X	978-0-07-237338-7	0-13-080859-8	13: 978-0-495-57052-3
Number of Pages	228	1049	388	579	313	398	151	362

Initial Determination of High School Age-Possible Capstone Engineering Design and Research Topics

The outcome of this research is very encouraging. Tables 2A and 2F indicate that: (1). **for Textbook 1**, 100% of all sections, and 100% of the volume is based on pre-calculus mathematics skills; (2) **for the Textbook 2**, 93.6% of all sections, and 97.1% of the volume is based on pre-calculus mathematics skills; (3) **for Textbook 3**, 97.4% of all sections, and 99.0% of the volume is based on pre-calculus mathematics skills; (4) **for Textbook 4**, 94.5% of all sections, and 96.0% of the volume is based on pre-calculus mathematics skills; (5) **for Textbook 5**, 97.9% of all sections, and 99.7% of the volume is based on pre-calculus mathematics skills; (6) **for Textbook 6**, 98.4% of all sections, and 99.0% of the volume is based on pre-calculus mathematics skills; and (7) **for Textbook 7**, 91.9% of all sections, and 93.4% of the volume is based on pre-calculus mathematics skills;

Table 2A. Statistic on Textbook 1 (Introduction to Engineering Design and Problem Solving, 2nd Edition by Arvid R. Eide, Roland D. Jenison, Lane H. Mashaw, and Larry L. Northup)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections				**Page Information**	
Mathematics		**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[four operations], [diagram], [graphs] (bar chart, etc.), [significant digit]		N/A	N/A	N/A	N/A
Calculus Level Mathematics					
Concepts and Skills	**Chapters/Sections**				
N/A	N/A			N/A	0
Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY Volume = Total Number of Pages – Number of Pages with Calculus Skills = 228 - 0 = 228 pages Number of Chapters = Total Number of Chapters – Number of Chapters with Calculus Skills = 6 – 0 = 6 chapters					
Statistical Summary					
Total Number of Pages Covered by Text (Excluding "Index"): 228			**Total Numbers of Chapters and Sections:** 6, 49		

Percentage of Pre-Calculus Sections	Percentage of Sections with Calculus Skills
$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{49}{49}\right)(100\%) = 100\%$	$\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{0}{49}\right)(100\%) = 0\%$
Total Numbers of Chapters with Pre-Calculus Skills Only: 6 out of 6	**Total Number of Pages with Pre-Calculus Skills Only:** 228 out of 228
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{228}{228}\right)(100\%) = 100.0\%$	

Conclusion on the Textbook:

(1) This short textbook (228 pages long) describes engineering design process in "plain English" and is suitable for the first engineering design project course at the upper-division level of undergraduate engineering program.
(2) The content of the book is basically "informational" and "descriptive," involving very little mathematics skills, which are limited to the following: [four operations], [diagram], [graphs] (bar chart, etc.), and [significant digit].
(3) Thus, the book or any book with similar knowledge content is also suitable for high school students in terms of mathematics preparation.

Table 2B. Statistic on Textbook 2 (Product Design Techniques in Reverse Engineering and New Product Development, by Kevin Otto and Kristin Wood)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections				**Page Information**	
Mathematics		**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[four operations], [power], [root], [trigonometric functions], [summation], [inequality], [set], [table], [chart] and [graph]		N/A	N/A	326, 346, 347, 435, 485, 486, 496, 504, 514, 523, 524, 526, 552-555, 610, 618, 626-628, 630-633, 639, 651-660, 688, 689, 698, 702, 703, 739, 765, 784-787, 794, 795. 802-804, 810, 813, 815, 817-820, 823-825, 828, 867-870, 900-908, 916, 917, 920-926, 929-933, 937, 939-948, 958, 961, 973, and 992-995	≈ 120

Calculus Level Mathematics		**Pages with Calculus Skills**		**Sections with Calculus Skills**	
Concepts and Skills	**Chapters/Sections**	**Page Numbers**	**Number of Pages**	**Page Numbers**	**Number of Pages**
[first order integral], [first degree derivative], and [first degree partial derivative]	11.VII. Advanced Method: Numerical Concept Scoring	522, 525	2	513-532	20
	13.V. Constructing Product Models: Basic Method	634, 636, 637	3	622-644	23
	16.V. Advanced Topic: A Discussion of Analytical Formulations	805, 809	2	805-810	6
	16.VI. Practical Optimization	814	1	811-821	11
	16.VII. Product Applications	826, 827	2	822-830	9
	18.IV. Statistical Analysis of Experiments	949	1	938-950	13
	19.III. Basic Method: Taguchi's Method	991	1	987-1000	14
	19.IV. Advanced Analysis: Probability Theory	1001-1007	7	1001-1007	7
Total Number of Pages			19		103

Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY

Volume (Pages with Pre-Calculus Skills) = Total Number of Pages – Number of Pages with Calculus Skills = 1049 - 19 = 1030 pages
Volume (Pages Excluding Sections with Calculus Skills) =
Total Number of Pages – Number of Pages of Sections with Calculus Skills = 1049 - 103 = 946
Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 19 - 5 = 14 chapters
Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 125 - 8 = 117 sections

Statistical Summary

Total Number of Pages Covered by Text	Total Numbers of Chapters and Sections:
(Excluding "Index"): 1049	19, 125

Percentage of Pre-Calculus Chapters

$$\%_{\substack{\text{Pre-Calculus}\\\text{Chapters}}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%)$$

$$= \left(\frac{14}{19}\right)(100\%) = 73.7\%$$

Percentage of Pre-Calculus Sections

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$$

$$= \left(\frac{117}{125}\right)(100\%) = 93.6\%$$

Average Percentage of Pre-Calculus Content

$$\%_{\substack{\text{Pre-Calculu}\\\text{Content}}} = \frac{\%_{\substack{\text{Pre-Calculus}\\\text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\\text{Sections}}}}{2} = \frac{73.7\% + 93.6\%}{2} = 83.7\%$$

Percentage of Chapters with Calculus Sections

$$\%_{\substack{\text{Calculus}\\\text{Chapters}}} = \left(\frac{\text{Number of Chapters with Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%)$$

$$= \left(\frac{5}{19}\right)(100\%) = 26.3\%$$

Percentage of Sections with Calculus Skills

$$\%_{\text{Calculus}} = \left(\frac{\text{Number of Sections with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$$

$$= \left(\frac{8}{125}\right)(100\%) = 6.4\%$$

Average Percentage of Calculus Content

$$\%_{\substack{\text{Calculus}\\\text{Content}}} = \frac{\%_{\substack{\text{Calculus}\\\text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\\text{Sections}}}}{2} = \frac{26.3\% + 6.4\%}{2} = 16.4\%$$

Total Number of Chapters with Pre-calculus Mathematics Skills: 14 out of 19
Total Number of Sections with both Pre-calculus and Calculus Mathematics Skills: 8 out of 125

Total Number of Pages with Pre-Calculus Skills Only: 1019 out of 1049

Percentage of Pre-Calculus Only Volume:

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{1019}{1049}\right)(100\%) = 97.1\%$$

Conclusion on the Textbook:

(1) The content of this book is basically descriptive and informational and include no homework assignment using engineering predictive and computational formulas.
(2) Out of a total of 1049 pages, and mostly in citing real-world product engineering and design case studies including those from patent libraries, only about 120 pages include pre-calculus level mathematics skills; and the pages involved are pages, and only about 30 pages contain formulas using beginning calculus skills such as; and the pages involved are pages.
(3) This book is age-possible for the high school level Capstone Engineering Design and Research course, in the futuristic K12 Engineering and Technology curriculum explored in the Vision Paper. This book could be used in the proposed Capstone Engineering Design & Research course as well.

Table 2C. Statistic on Textbook 3 (Engineering Design by Rudolph J. Eggert)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections				**Page Information**			
Mathematics		**Physics**	**Chemistry**	**Pages with Calculus Skills**		**Sections with Calculus Skills**	
				Page Numbers	**Number of Pages**	**Page Numbers**	**Number of Pages**
[four operation], [power], [root], [units], [chart], [graphs]		N/A	N/A	N/A	N/A	N/A	N/A
Calculus Level Mathematics							
Concepts and Skills	**Chapters/Sections**						
[first integral], [first derivative]	8.3 Systematic Parametric Design: Belt-and-Pulley Example			190, 191	2	188-199	12
	10. 4 Tolerance Design			241, 242	2	237-245	9
Total Number of Pages					4		21

Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY
Volume (Pages with Pre-Calculus Skills) = Total Number of Pages – Number of Pages with Calculus Skills = 388 - 4 = 384 pages
Volume (Pages Excluding Sections with Calculus Skills) =
Total Number of Pages – Number of Pages of Sections with Calculus Skills = 388 - 21 = 367
Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 14 - 2 = 12 chapters
Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 85 - 2 = 83 sections

Statistical Summary

Total Number of Pages Covered by Text (Excluding “Index”): 388	**Total Numbers of Chapters and Sections:** 14, 85

Percentage of Pre-Calculus Chapters

$$\%_{\substack{\text{Pre-Calculus}\\\text{Chapters}}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%)$$

$$= \left(\frac{12}{14}\right)(100\%) = 85.7\%$$

Percentage of Pre-Calculus Sections

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$$

$$= \left(\frac{83}{85}\right)(100\%) = 97.4\%$$

Average Percentage of Pre-Calculus Content

$$\%_{\substack{\text{Pre-Calculu}\\\text{Content}}} = \frac{\%_{\substack{\text{Pre-Calculus}\\\text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\\text{Sections}}}}{2} = \frac{85.7\% + 97.4\%}{2} = 91.6\%$$

Percentage of Chapters with Calculus Sections

$$\%_{\substack{\text{Calculus}\\\text{Chapters}}} = \left(\frac{\text{Number of Chapters with Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%)$$

$$= \left(\frac{2}{14}\right)(100\%) = 14.3\%$$

Percentage of Sections with Calculus Skills

$$\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$$

$$= \left(\frac{2}{85}\right)(100\%) = 2.4\%$$

Average Percentage of Calculus Content

$$\%_{\substack{\text{Calculus}\\\text{Content}}} = \frac{\%_{\substack{\text{Calculus}\\\text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\\text{Sections}}}}{2} = \frac{14.3\% + 2.4\%}{2} = 8.4\%$$

Total Numbers of Chapters with Pre-Calculus Skills Only:	Total Number of Pages with Pre-Calculus Skills Only:
12 out of 14	384 out of 388

Percentage of Pre-Calculus Volume:

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{384}{388}\right)(100\%) = 99.0\%$$

Conclusion on the Textbook:

(1) This is a handy textbook for a college or university undergraduate senior year design project course, as a reference for understanding engineering design process.

(2) For an overwhelming majority of chapters and sections, the mathematics concepts and skills required for reading include only the very basics such as [four operation], [power], [root], [units], [chart], and [graphs].

(3) Chapters 8 and 10 involve a few beginning calculus skills such as [first integral] and [first derivative]; these skills could be taught as special mathematics topics or the relevant sections could be omitted.

(4) No physics or chemistry skills except at descriptive or informational level is required. Topics of probabilities and statistics, engineering economics and engineering ethics are covered in this book as well.

(5) For all practical purposes, this book could be used by high school graduation year students, in the Capstone Engineering Design & Research course.

Table 2D. Statistic on Textbook 4 (Fundamentals of Engineering Design, 2nd Edition, by Barry Hyman)

<table>
<tr><th colspan="4">Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections</th><th colspan="4">Page Information</th></tr>
<tr><th colspan="2" rowspan="2">Mathematics</th><th rowspan="2">Physics</th><th rowspan="2">Chemistry</th><th colspan="2">Pages with Calculus Skills</th><th colspan="2">Sections with Calculus Skills</th></tr>
<tr><th>Page Numbers</th><th>Number of Pages</th><th>Page Numbers</th><th>Number of Pages</th></tr>
<tr><td colspan="2">[four operations], [inequality], [root], [limits], [flow chart], [trigonometric functions], [flow diagram], [summation], [data tables] and [matrix]</td><td>N/A</td><td>N/A</td><td>N/A</td><td></td><td>N/A</td><td></td></tr>
<tr><th colspan="4">Calculus Level Mathematics</th><td colspan="4" rowspan="2"></td></tr>
<tr><th>Concepts and Skills</th><th colspan="3">Chapters/Sections</th></tr>
<tr><td rowspan="6">[first integral], [first derivative], [second integral], [second derivative], [first partial derivative], [second partial derivatives]</td><td colspan="3">Section 5.2 Basic Probability Concepts</td><td>213-215</td><td>3</td><td>212-219</td><td>8</td></tr>
<tr><td colspan="3">Section 5.4 Functions of a Random Variable</td><td>226, 227</td><td>2</td><td>226-228</td><td>3</td></tr>
<tr><td colspan="3">Section 5.6 Reliability</td><td>236, 239, 240</td><td>3</td><td>235-240</td><td>6</td></tr>
<tr><td colspan="3">Section 10.7 Nonlinear Programming</td><td>512</td><td>1</td><td>500-513</td><td>14</td></tr>
<tr><td colspan="3">Section 10.8 Global Optimum</td><td>515- 522</td><td>8</td><td>513-522</td><td>10</td></tr>
<tr><td colspan="3">Section 10.11 Lagrange Multipliers</td><td>536, 537, 540, 542, 550, 551, 552</td><td>7</td><td>535-553</td><td>19</td></tr>
<tr><td colspan="4">Total Number of Pages</td><td></td><td>24</td><td></td><td>60</td></tr>
<tr><td colspan="8">Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY
Volume (Pages with Pre-Calculus Skills) = Total Number of Pages – Number of Pages with Calculus Skills = 579 - 24 = 555 pages
Volume (Pages Excluding Sections with Calculus Skills) =
Total Number of Pages – Number of Pages of Sections with Calculus Skills = 579 - 60 = 519
Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 10 - 2 = 8 chapters
Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 109 - 6 = 103 sections</td></tr>
</table>

Statistical Summary	
Total Number of Pages Covered by Text (Excluding "Index"): 579	**Total Numbers of Chapters and Sections:** 10, 109
Percentage of Pre-Calculus Chapters $\%_{\text{Pre-Calculus Chapters}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%) = \left(\frac{8}{10}\right)(100\%) = 80.0\%$ **Percentage of Pre-Calculus Sections** $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%) = \left(\frac{103}{109}\right)(100\%) = 94.5\%$ **Average Percentage of Pre-Calculus Content** $\%_{\text{Pre-Calculu Content}} = \frac{\%_{\text{Pre-Calculus Chapters}} + \%_{\text{Pre-Calculus Sections}}}{2} = \frac{80.0\% + 94.5\%}{2} = 87.3\%$	**Percentage of Chapters with Calculus Sections** $\%_{\text{Calculus Chapters}} = \left(\frac{\text{Number of Chapters with Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%) = \left(\frac{2}{10}\right)(100\%) = 20.0\%$ **Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%) = \left(\frac{6}{109}\right)(100\%) = 5.5\%$ **Average Percentage of Calculus Content** $\%_{\text{Calculus Content}} = \frac{\%_{\text{Calculus Chapters}} + \%_{\text{Pre-Calculus Sections}}}{2} = \frac{20.0\% + 5.5\%}{2} = 12.8\%$
Total Numbers of Chapters with Pre-Calculus Skills Only: 8 out of 10	**Total Number of Pages with Pre-Calculus Skills Only:** 555 out of 579
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{555}{578}\right)(100\%) = 96.0\%$	

Conclusion on the Textbook:

(1) This book covers many topics related to engineering design process, such as concept generation, probabilities and statistics, project planning, engineering economics and many others. The content of this book is basically descriptive and informational.
(2) Mathematics-based predictive and computational formulas contained in some pages are mostly at pre-calculus level.
(3) 2 Chapters (6 Sections) involve beginning calculus skills, which could be taught as special mathematics topics, or the Chapters or Sections could be omitted.
(4) Little prior knowledge or skills in physics or chemistry is needed for reading and homework assignments.
(5) This book could be used in the Capstone Engineering Design and Research course.

Table 2E. Statistic on Textbook 5 (An Introduction to Mechanical Engineering by Jonathan Wickert)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			Page Information			
Mathematics	Physics	Chemistry	Pages with Calculus Skills		Sections with Calculus Skills	
			Page Numbers	Number of Pages	Page Numbers	Number of Pages
[four operations], [length], [volume], [systems of units], summation], [square], [trigonometric functions], [right triangle], [oblique triangles]	[force], [mass], [gravity], [density], [time], [moment of force], [energy], [work], [pressure], [power], [heat], [luminous intensity], [viscosity], [angular velocity], [torque]	N/A	N/A	N/A	N/A	N/A
Calculus Level Mathematics						
Concepts and Skills	**Chapters/Sections**					
[first derivative], [first integral], [chain rule]	7.6 Engine and Compressor Mechanisms		257	1	255-259	5
Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY Volume (Pages with Pre-Calculus Skills) = Total Number of Pages – Number of Pages with Calculus Skills = 313 - 1 = 312 pages Volume (Pages Excluding Sections with Calculus Skills) = Total Number of Pages – Number of Pages of Sections with Calculus Skills = 313 - 5 = 308 Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 8 - 1 = 7 chapters Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 48 - 1 = 47 sections						

Statistical Summary	
Total Number of Pages Covered by Text (Excluding "Index"): 313	**Total Numbers of Chapters and Sections:** 8, 48

Percentage of Pre-Calculus Chapters

$$\%_{\substack{\text{Pre-Calculus}\\ \text{Chapters}}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%)$$

$$= \left(\frac{7}{8}\right)(100\%) = 87.5\%$$

Percentage of Pre-Calculus Sections

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$$

$$= \left(\frac{46}{47}\right)(100\%) = 97.9\%$$

Average Percentage of Pre-Calculus Content

$$\%_{\substack{\text{Pre-Calculu}\\ \text{Content}}} = \frac{\%_{\substack{\text{Pre-Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{87.5\% + 97.9\%}{2} = 92.7\%$$

Percentage of Chapters with Calculus Sections

$$\%_{\substack{\text{Calculus}\\ \text{Chapters}}} = \left(\frac{\text{Number of Chapters with Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%)$$

$$= \left(\frac{1}{8}\right)(100\%) = 12.5\%$$

Percentage of Sections with Calculus Skills

$$\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$$

$$= \left(\frac{1}{47}\right)(100\%) = 2.1\%$$

Average Percentage of Calculus Content

$$\%_{\substack{\text{Calculus}\\ \text{Content}}} = \frac{\%_{\substack{\text{Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{12.5\% + 2.1\%}{2} = 7.3\%$$

Total Numbers of Chapters with Pre-Calculus Skills Only:	**Total Number of Pages with Pre-Calculus Skills Only:**
7 out of 8	312 out of 313

Percentage of Pre-Calculus Volume:

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{312}{313}\right)(100\%) = 99.7\%$$

Conclusion on the Textbook:

(1) This book is intended for students in the first or second years of a college or university program in mechanical engineering, and it gives a general overview of some topics of science and mechanical engineering, such as machine components and tools, forces in structures and fluids, materials and stresses, thermal and energy systems, motion of machinery, and mechanical design.

(2) Some chapters are purely descriptive and informational in knowledge content, while others involve review of basic physics with scientific principles and computational formulas. The mathematics concepts skills needed for understanding the content of the book are all at pre-calculus level except in Section 7.6 (Engine and Compressor Mechanisms), beginning calculus skills such as [first derivative], [first integral, and [chain rule] are found in page 257. These could be taught as special mathematics topics or the involved Section could be omitted.

(3) The physics and chemistry concepts and skills involved in the topics of this book are very basics and could be taught as special topics as well.

(4) The topics in the book include basic concepts and computational skills usually covered in typical strength of materials, fluid mechanics, heat transfer, and mechanical design courses.

(5) Carefully selected chapters in this book could be used in the Capstone Engineering Design and Research course in the futuristic K12 Engineering and Technology curriculum, as explored in the Vision Paper.

Table 2F. Statistic on Textbook 6 (The Mechanical Design Process, 3rd Edition by David G. Ullman)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			**Page Information**			
			Pages with Calculus Skills		**Sections with Calculus Skills**	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**	**Page Numbers**	**Number of Pages**
[four operations], [power], [function], graph], [schematics], [summation], [root], [power], [chart], [graph], [probability]	[rotation], [force], [energy]	N/A	N/A	N/A	N/A	N/A
Calculus Level Mathematics						
Concepts and Skills	**Chapters/Sections**					
[first integral], [partial derivative]	11.7 Sensitivity Analysis		273, 274	2	272-274	3
	11.8 Robust Design by Analysis		276	1	275-277	3
	Appendix B.1 Introduction		359	1	357-361	5
Total Number of Pages				4		11

Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY

Volume (Pages with Pre-Calculus Skills) = Total Number of Pages – Number of Pages with Calculus Skills = 398 - 4 = 394 pages

Volume (Pages Excluding Sections with Calculus Skills) =

Total Number of Pages – Number of Pages of Sections with Calculus Skills = 398 - 11 = 387

Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 13 - 1 = 12 chapters

Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 124 - 2 = 122 sections

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 398	**Total Numbers of Chapters and Sections:** 13, 124

<table>
<tr>
<td>Percentage of Pre-Calculus Chapters
$\%_{\substack{\text{Pre-Calculus}\\ \text{Chapters}}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%)$
$= \left(\frac{12}{13}\right)(100\%) = 92.3\%$
Percentage of Pre-Calculus Sections
$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$
$= \left(\frac{122}{124}\right)(100\%) = 98.4\%$
Average Percentage of Pre-Calculus Content
$\%_{\substack{\text{Pre-Calculu}\\ \text{Content}}} = \frac{\%_{\substack{\text{Pre-Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{92.3\% + 98.4\%}{2} = 95.4\%$</td>
<td>Percentage of Chapters with Calculus Sections
$\%_{\substack{\text{Calculus}\\ \text{Chapters}}} = \left(\frac{\text{Number of Chapters with Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%)$
$= \left(\frac{1}{13}\right)(100\%) = 7.7\%$
Percentage of Sections with Calculus Skills
$\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$
$= \left(\frac{2}{124}\right)(100\%) = 1.6\%$
Average Percentage of Calculus Content
$\%_{\substack{\text{Calculus}\\ \text{Content}}} = \frac{\%_{\substack{\text{Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{7.7\% + 1.6\%}{2} = 4.7\%$</td>
</tr>
<tr>
<td>Total Numbers of Chapters with Pre-Calculus Skills Only:
12 out of 13</td>
<td>Total Number of Pages with Pre-Calculus Skills Only:
394 out of 398</td>
</tr>
<tr>
<td colspan="2">Percentage of Pre-Calculus Volume:
$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{394}{398}\right)(100\%) = 99.0\%$</td>
</tr>
<tr>
<td colspan="2">Conclusion on the Textbook:
(1) This is a suitable textbook for a high school graduation year capstone engineering design course in the mechanical engineering pathways.
(2) Although in the cited examples, mathematics concepts and skills such as [four operations], [power], [function], graph], [schematics], [summation], [root], [power], [chart], [graph], [probability], [first integral], and [partial derivative], as well as physics concepts such as [rotation], [force], and [energy] are used, the content in this book is basically descriptive and informational.</td>
</tr>
</table>

Table 2G. Statistic on Textbook 7 (Engineering Success by Peter Schiavone)

<table>
<tr>
<th colspan="4">Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections</th>
<th colspan="4">Page Information</th>
</tr>
<tr>
<th colspan="2" rowspan="2">Mathematics</th>
<th rowspan="2">Physics</th>
<th rowspan="2">Chemistry</th>
<th colspan="2">Pages with Calculus Skills</th>
<th colspan="2">Sections with Calculus Skills</th>
</tr>
<tr>
<th>Page Numbers</th>
<th>Number of Pages</th>
<th>Page Numbers</th>
<th>Number of Pages</th>
</tr>
<tr>
<td colspan="2">[four operations], [function], [trigonometric functions], [power], [root], [infinity], [inequality], [summation], [limit], [radius], [area of triangle](base and heights)</td>
<td>[velocity] (linear and angular), [acceleration], [time], [energy], [work], [mass]</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<th colspan="4">Calculus Level Mathematics</th>
<td colspan="4" rowspan="2"></td>
</tr>
<tr>
<th>Concepts and Skills</th>
<th colspan="3">Chapters/Sections</th>
</tr>
<tr>
<td rowspan="3">[first integral], [first derivative], [second integral], [second derivative], and [chain rule]</td>
<td colspan="3">7.1 Solving Problems that Require Mainly Application: Type A</td>
<td>111, 112</td>
<td>2</td>
<td>108-112</td>
<td>5</td>
</tr>
<tr>
<td colspan="3">7.2 Solving Problems of Type B: Word Problems</td>
<td>118, 120</td>
<td>2</td>
<td>113-123</td>
<td>11</td>
</tr>
<tr>
<td colspan="3">8.1 How to Succeed in Mathematics Courses</td>
<td>128-133</td>
<td>6</td>
<td>126-133</td>
<td>8</td>
</tr>
<tr>
<td colspan="4">Total Number of Pages</td>
<td></td>
<td>10</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td colspan="8">Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY
Volume (Pages with Pre-Calculus Skills) = Total Number of Pages - Number of Pages with Calculus Skills = 151 - 10 = 141 pages
Volume (Pages Excluding Sections with Calculus Skills) =
Total Number of Pages – Number of Pages of Sections with Calculus Skills = 151 - 24 = 127
Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 10 - 2 = 8 chapters
Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 37 - 3 = 34 sections</td>
</tr>
<tr>
<th colspan="8">Statistical Summary</th>
</tr>
<tr>
<td colspan="4">Total Number of Pages Covered by Text
(Excluding “Index”): 151</td>
<td colspan="4">Total Numbers of Chapters and Sections:
10, 37</td>
</tr>
<tr>
<td colspan="4">Percentage of Pre-Calculus Chapters
$\%_{\substack{\text{Pre-Calculus}\\ \text{Chapters}}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%)$
$= \left(\frac{8}{10}\right)(100\%) = 80.0\%$</td>
<td colspan="4">Percentage of Chapters with Calculus Sections
$\%_{\substack{\text{Calculus}\\ \text{Chapters}}} = \left(\frac{\text{Number of Chapters with Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%)$
$= \left(\frac{2}{10}\right)(100\%) = 20.0\%$</td>
</tr>
</table>

Percentage of Pre-Calculus Sections	Percentage of Sections with Calculus Skills
$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%) = \left(\frac{34}{37}\right)(100\%) = 91.9\%$	$\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%) = \left(\frac{3}{37}\right)(100\%) = 8.1\%$
Average Percentage of Pre-Calculus Content $\%_{\substack{\text{Pre-Calculu}\\ \text{Content}}} = \frac{\%_{\substack{\text{Pre-Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{80.0\% + 91.9\%}{2} = 86.0\%$	**Average Percentage of Calculus Content** $\%_{\substack{\text{Calculus}\\ \text{Content}}} = \frac{\%_{\substack{\text{Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{20.0\% + 8.1\%}{2} = 14.1\%$
Total Numbers of Chapters with Pre-Calculus Skills Only: 8 out of 10	**Total Number of Pages with Pre-Calculus Skills Only:** 141 out of 151
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{141}{151}\right)(100\%) = 93.4\%$	

Conclusion on the Textbook:

(1) This is a handy book that teaches how to succeed in college undergraduate engineering program. In this book, in the examples cited, some mathematics concepts and skills at both pre-calculus and calculus levels have been used; similarly, some physics concepts appear in some cited examples.
(2) However, the content of the book is basically descriptive and informational.
(3) Thus, for all practical purposes, this book is suitable for high school students in the capstone engineering design project course.

Table 2H. Statistic on Textbook 8 (Technology and the Future, 11th Edition, edited by Albert H. Teich)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			Page Information	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
N/A	N/A	N/A	N/A	N/A
Calculus Level Mathematics				
Concepts and Skills	**Chapters/Sections**			
N/A	N/A		N/A	0

Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY

Volume = Total Number of Pages – Number of Pages with Calculus Skills = 362 - 0 = 362 pages

Number of Chapters = Total Number of Chapters – Number of Chapters with Calculus Skills = 6 – 0 = 6 chapters

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 362	Total Numbers of Chapters and Sections: 6, 27
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%) = \left(\frac{27}{27}\right)(100\%) = 100\%$	**Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%) = \left(\frac{0}{27}\right)(100\%) = 0\%$
Total Numbers of Chapters with Pre-Calculus Skills Only: 25 out of 25	**Total Number of Pages with Pre-Calculus Skills Only:** 362 out of 362
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{362}{362}\right)(100\%) = 100\%$	

Conclusion on the Textbook:

(1) This book is a collection of thought-provoking articles by scholars across the Nation and world-wide, dealing with a wide variety of subjects related to the interaction between technology and other issues such as morals, business ethics, economics, politics, civil rights, legal implications, climate change, ecology, genetics, stem cell research, and terrorism, which are directly or indirectly related to the development of technologies, at a philosophical and metaphysical level.
(2) One of the scholars even uses the expression of "Technology: The Opiate of the Intellectuals" to question our age-old assumption that tends to place an equal sign between technology and progress. This book is descriptive and informational, no mathematics skill is needed for reading.

Conclusions and Recommendations

This report has presented (1) information about seven college-level senior-year engineering design textbooks selected for the initial determination and selection of high school age-possible topics (Table 1), and (2) the outcome of the research on the inclusion of mathematics, physics and chemistry concepts and skills needed for reading and homework assignments (Tables 2A through 2H). The following are recommended: generic engineering design project-based courses have been taught in many high schools across the United States; real-world design projects could be developed for using CADD technology to create everyday products and systems, and the learning outcomes could be compared with those of students form colleges and universities.

References

Committee on K-12 Engineering Education (2009). *Engineering in K-12 education: Understanding the status and improving the prospects*. Washington, DC: National Academy of Engineering and the National Research Council.

Hacker, M. (2011). Private email correspondence, Saturday, January 22, 2011, 4:58:44 PM.

Lewis, T. (2007). Engineering education in schools. *International Journal of Engineering Education*, 23(5), 843-852.

Locke, E. (2009a). Proposed model for a streamlined, cohesive, and optimized k-12 STEM curriculum with a focus on engineering. *The Journal of Technology* Studies. Volume XXXV, Number 2, Winter 2009. Retrieved Thursday, February 17, 2011 from http://scholar.lib.vt.edu/ejournals/JOTS/v35/v35n2/pdf/locke.pdf.

Locke, E. (2009b). *Report on the achievements of K-12 engineering education in Australia & its positive referential values for the evolution of a potentially viable K-12 engineering & technology curriculum in the United States*. Unpublished research document.

Smith, P. C., & Wicklein, R. C. (2007). *Identifying the essential aspects and related academic concepts of an engineering design curriculum in secondary technology education.* Unpublished internal research report, NCETE. Retrieved January 30, 2009 from http://ncete.org/flash/publications.php.

About the Author:

Edward Locke is a product designer, CADD specialist, digital graphic artist, and independent scholar on K12 STEAM issues. He taught engineering graphics and CADD technology with product design projects to students from diverse ethnic backgrounds (Latino, Vietnamese-, African-, Caucasian-Americans, and others) at Santa Ana College, California (2000-2007) as an adjunct instructor, practiced product design and graphic design (1994-2014), pursued graduate studies at California State University Los Angeles (2004-2007) and then at the University of Georgia as a National Center for Engineering and Technology Education Fellow (2007-2009). He graduated in 2009 with an Education Specialist degree from the College of Education, Department of

Workforce Education, Leadership and Social Foundations at The University of Georgia, Athens. He is currently working on issues of K12 engineering and technology curriculum, in collaboration with professors of the Engineering Department, at East Los Angeles College; and he could be reached at edwardnlocke@yahoo.com. Edward Locke's professional works, college-level textbooks and instructional materials, as well as research writings and curriculum development documents are featured in his four websites: (1) Scholar STEAM K12 Plus (K12 engineering and technology curriculum at http://scholarsteamk12plus.weebly.com/), (2) SuniSea Products (consumer product design, engineering graphics and CADD technology at http://suniseaproducts.weebly.com/), (3) SuniSea Design (graphic design and visual communication at http://suniseadesign.weebly.com/), and (4) SuniSea Creation (traditional and digital arts at http://suniseacreation.weebly.com/).

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