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

Statistics on High School
Age-Possible Engineering Graphics, CADD and Product Design 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 (Engineering Graphics, CADD and Product Design)

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) selection of data source (selection of popular university undergraduate engineering textbooks and other instructional and learning materials); (2) analysis of data source (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) comparison (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.

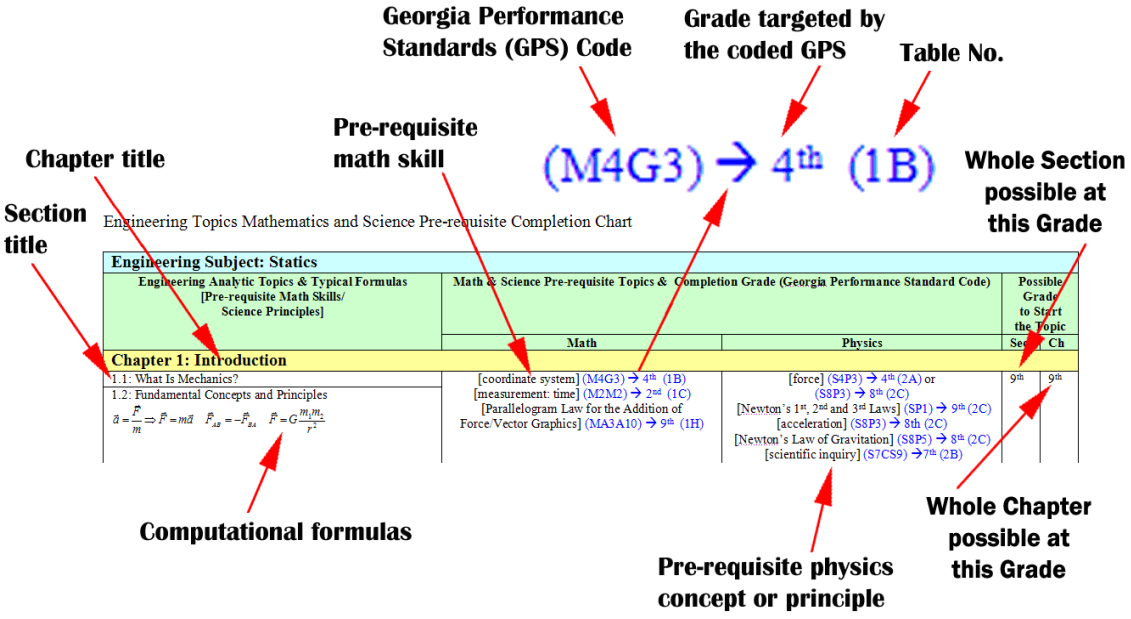

Figure 1. The original research data table used to initially determine high school 9th Grade age-possible statics topics.

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 engineering graphics, CADD and product design, 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 Textbooks 1-6 plus my FREE online textbooks are mostly descriptive and informational. Therefore, for all practical purposes, all pages of the textbooks 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 6, plus my two FREE online textbooks.

Sources of Data

Table 1 lists the college-level Textbooks 1 through 6 used for the extraction of analytic and predictive principles and computational formulas related to the subject of engineering graphics, CADD (computer-aided drafting/design) and product design.

Table 1. Data Source (Engineering Graphics, CADD and Product Design Textbooks)

	Textbooks Examined					
	Textbook 1	**Textbook 2**	**Textbook 3**	**Textbook 4**	**Textbook 5**	**Textbook 6**
Title	Technical Graphics Communication, 3rd Edition	Engineering Graphics with AutoCAD 2006	Technical Drawing, 4th Edition	Engineering Drawing and Design, 6th Edition	Engineering Graphics, 4th Edition	Applied Descriptive Geometry, 2nd Edition
Authors	Gary R. Bertoline and Eric N. Wiebe	James D. Bethune	David L. Goetsch, William S. Chalk, and John A. Nelson	Cecil Jensen, Jay D. Helsel, and Dennis R. Short	Frederick E. Giesecke, Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, Robert Olin Loving, and John Thomas Dygdon	Kathryn Holliday-Darr
Publisher	McGraw-Hill Higher Education	Pearson Prentice Hall	Delmar Publishers	Glencoe McGraw-Hill	Macmillan Publishing Company	Delmar Publishers
Year	2003	2006	2000	2002	1987	1998
ISBN	0-07-365598-8	0-13-171391-4	0-7668-0531-X	0-07-826611-4	0-02-342760-4	0-8273-7912-9
Number of Pages	1234	768	1043	1059	949	473

	Textbooks Examined				
	Textbook 7	**Textbook 8**	**Textbook 9**	**Textbook 10**	**Textbook 11**
Title	Basic Blueprint Reading and Sketching, 7th Edition	Fundamentals of Geometric Dimensioning and Tolerancing, 2nd Edition	A Comprehensive Introduction to SolidWorks 2011	Official Guide to Certified SolidWorks Associate Exams: CSWA, CSDA, CSWSA-FEA SolidWorks 2012-2013	Product Design Techniques in Reverse Engineering and New Product Development
Authors	C. Thomas Olivo and Thomas P. Olivo	Alex Krulikowski	Godfrey Onwubolu	David C. Planchard	Kevin Otto and Kristin Wood
Publisher	Delmar Publishers	Delmar Publisher	SDC Publications	Schroff Development Corporation	Prentice Hall (Pearson Education)
Year	1999	1998	2011	2013	2000
ISBN	0-7668-0841-6	0-8273-7995-1	978-1-58503-655-4	978-1-58503-753-7	0-13-021271-7
Number of Pages	218	382	802	316	1049

Initial Determination of High School Age-Possible Engineering Graphics, CADD and Product Design Topics

The outcome of this research is very encouraging. Tables 2A through 2F indicate that: (1). **for all selected Textbook 1, 2, 4, 6, and 7 through 10**, 100% of all sections, and 100 % of the volume is based on pre-calculus mathematics skills; (2) **for the selected Textbook 3**, 99.2% of all sections (or 83.7% of content), and 97.5 % of the volume is based on pre-calculus mathematics skills; (3) **for the selected Textbook 5**, 97.6% of all sections (or 83.7% of content), and 98.6% of the volume is based on pre-calculus mathematics skills; (4) **for the selected Textbook 11**, 93.6% of all sections (or 83.7% of content), and 97.1 % of the volume is based on pre-calculus mathematics skills; (5) **for my FREE Online Textbook** (*Engineering Descriptive Geometry: A Collection of Teaching & Learning Modules for the*

Dummies with Autodesk AutoCAD& Inventor, and *Industrial Product Design in the Age of Globalization and Digital Revolution*), 100% of all sections, and 100 % of the volume is based on pre-calculus mathematics skills; and (6) for all practical purposes, no prior mastery of physics and chemistry concepts or skills is needed for reading and homework assignments.

Table 2A. Statistic on Textbook 1 (Technical Graphics Communication, 3rd Edition, by Gary R. Bertoline and Eric N. Wiebe)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			**Page Information**	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[systems of units], [fraction], [scale], [angle], [square root], [power], [perpendicularity], [parallelism], [coordinates] (axes, planes, origin), [measurement] (length, width, height), [point], [space], [conic curves] (parabolas, hyperbolas, and ellipses), [roulette] (spirals and cycloids), [double-curved lines] (helixes, etc.), [constructive solid geometry] (union, difference and intersection)	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 = 1234 - 0 = 1234 pages Number of Chapters = Total Number of Chapters – Number of Chapters with Calculus Skills = 25 – 0 = 25 chapters				
Statistical Summary				
Total Number of Pages Covered by Text (Excluding "Index"): 1234		**Total Numbers of Chapters and Sections:** 25, 216		
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{216}{216}\right)(100\%) = 100\%$		**Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{0}{216}\right)(100\%) = 0\%$		
Total Numbers of Chapters with Pre-Calculus Skills Only: 25 out of 25		**Total Number of Pages with Pre-Calculus Skills Only:** 1234 out of 1234		
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{1234}{1234}\right)(100\%) = 100\%$				
Conclusion on the Textbook: (1) Based on my previous teaching experience, students only need to learn the basics of the above mathematics concepts and skills, including some formulas or expressions for the curves. (2) The focus is graphical construction, not mathematics. Engineering graphics has been taught at many high schools and some middle schools as well with great success.				

Table 2B. Statistic on Textbook 2 (Engineering Graphics with AutoCAD 2006 by James D. Bethune)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			**Page Information**	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[systems of units], [fraction], [scale], [angle], [square root], [power], [perpendicularity], [parallelism], [coordinates] (axes, planes, origin), [measurement] (length, width, height), [point], [space], [conic curves] (parabolas, hyperbolas, and ellipses), [roulette] (spirals and cycloids), [double-curved lines] (helixes, etc.), [constructive solid geometry] (union, difference and intersection)	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 = 768 - 0 = 768 pages
Number of Chapters = Total Number of Chapters – Number of Chapters with Calculus Skills = 17 – 0 = 17 chapters

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 768	**Total Numbers of Chapters and Sections:** 17, 367
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{367}{367}\right)(100\%) = 100\%$	**Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{0}{367}\right)(100\%) = 0\%$
Total Numbers of Chapters with Pre-Calculus Skills Only: 17 out of 17	**Total Number of Pages with Pre-Calculus Skills Only:** 768 out of 768
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{768}{768}\right)(100\%) = 100\%$	

Conclusion on the Textbook:

(1) This textbook has a strong focus on using different tools and setting in AutoCAD to solve engineering graphics problems.
(2) The mathematics skills needed for textbook reading and homework assignments are all at pre-calculus level.

Table 2C. Statistic on Textbook 3 (Technical Drawing, 4th Edition by David L. Goetsch, William S. Chalk, and John A. Nelson)

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**
[systems of units], [fraction], [scale], [angle], [square root], [power], [perpendicularity], [parallelism], [coordinates] (axes, planes, origin), [measurement] (length, width, height), [space], [point], [conic curves] (parabolas, hyperbolas, and ellipses), [roulette] (spirals and cycloids), [double-curved lines] (helixes, etc.), [constructive solid geometry] (union, difference and intersection), [log], [natural log]	N/A	N/A	N/A		N/A	
Calculus Level Mathematics						
Concepts and Skills	**Chapters/Sections**					
[first integral], [first derivative]	Functional Classes: An Overview		840, 841	2	836-840	5
	Specific Charts and Graphs		846-851, 870-880	26	841-881	41
Total Number of Pages				26		46

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 = 1043 - 26 = 1017 pages
Volume (Pages Excluding Sections with Calculus Skills) =
Total Number of Pages – Number of Pages of Sections with Calculus Skills = 1043 - 46 = 997
Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 26 - 1 = 25 chapters
Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 238 - 2 = 236 sections

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 1043	**Total Numbers of Chapters and Sections:** 26, 238
Percentage of Pre-Calculus Chapters $\%_{\substack{\text{Pre-Calculus}\\\text{Chapters}}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%)$ $= \left(\frac{25}{26}\right)(100\%) = 96.2\%$ **Percentage of Pre-Calculus Sections**	**Percentage of Chapters with Calculus Sections** $\%_{\substack{\text{Calculus}\\\text{Chapters}}} = \left(\frac{\text{Number of Chapters with Calculus Sections}}{\text{Total Number of Chapters}}\right)(100\%)$ $= \left(\frac{1}{26}\right)(100\%) = 3.8\%$ **Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sections with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{2}{238}\right)(100\%) = 0.8\%$

$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{236}{238}\right)(100\%) = 99.2\%$ **Average Percentage of Pre-Calculus Content** $\%_{\substack{\text{Pre-Calculu}\\\text{Content}}} = \frac{\%_{\substack{\text{Pre-Calculus}\\\text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\\text{Sections}}}}{2} = \frac{96.2\% + 99.2\%}{2} = 97.7\%$	**Average Percentage of Calculus Content** $\%_{\substack{\text{Calculus}\\\text{Content}}} = \frac{\%_{\substack{\text{Calculus}\\\text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\\text{Sections}}}}{2} = \frac{3.8\% + 0.8\%}{2} = 2.3\%$
Total Number of Chapters with Pre-calculus Mathematics Skills: 25 out of 26 **Total Number of Sections with both Pre-calculus and Calculus Mathematics Skills:** 236 out of 238	**Total Number of Pages with Pre-Calculus Skills Only:** 1017 out of 1043
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{1017}{1043}\right)(100\%) = 97.5\%$	
Conclusion on the Textbook: (1) This is one of the best textbooks on engineering graphics that I have collected. (2) Except for Chapter 23 (pages 833-881), all mathematics concepts and skills needed for textbook reading and homework assignments are at pre-calculus level.	

Table 2D. Statistic on Textbook 4 (Engineering Drawing and Design, 6th Edition by Cecil Jensen, Jay D. Helsel, and Dennis R. Short)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			**Page Information**	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[systems of units], [fraction], [scale], [angle], [square root], [power], [perpendicularity], [parallelism], [coordinates] (axes, planes, origin), [measurement] (length, width, height), [point], [space], [conic curves] (parabolas, hyperbolas, and ellipses), [roulette] (spirals and cycloids), [double-curved lines] (helixes, etc.), [constructive solid geometry] (union, difference and intersection)	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 = 1059 - 0 = 1059 pages Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 27 - 0 = 27 chapters				
Statistical Summary				
Total Number of Pages Covered by Text (Excluding "Index"): 1059			**Total Numbers of Chapters and Sections:** 27, 183	
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{183}{183}\right)(100\%) = 100\%$			**Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{0}{183}\right)(100\%) = 0\%$	
Total Numbers of Chapters with Pre-Calculus Skills Only: 27 out of 27			**Total Number of Pages with Pre-Calculus Skills Only:** 1059 out of 1059	
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{1059}{1059}\right)(100\%) = 100\%$				
Conclusion on the Textbook: (1) This textbook is beautifully illustrated with photos, pictures, colorful tables and graphs; and includes a great wealth of do's and don'ts in real world mechanical component design. (2) All mathematics concepts and skills needed for textbook reading and homework assignments are at pre-calculus level.				

Table 2E. Statistic on Textbook 5 (Engineering Graphics, 4th Edition by Frederick E. Giesecke, Alva Mitchell, Henry Cecil Spencer, Ivan Leroy Hill, Robert Olin Loving, and John Thomas Dygdon)

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**
[systems of units], [fraction], [scale], [angle], [square root], [power], [perpendicularity], [parallelism], [coordinates] (axes, planes, origin), [measurement] (length, width, height), [point], [space], [conic curves] (parabolas, hyperbolas, and ellipses), [roulette] (spirals and cycloids), [double-curved lines] (helixes, etc.), [constructive solid geometry] (union, difference and intersection), [log], [natural log]	N/A	N/A	N/A		N/A	
Calculus Level Mathematics						
Concepts and Skills	**Chapters/Sections**					
[first integral], [first derivative]	29.2 The Graphical Calculus		812-814	3	811-826	16
	29.3 The Differential calculus					
	29.4 Geometric Interpretation of the Derivative					
	29.5 Graphical Differentiation - The Slope Law					
	29.7 Graphical Differentiation Using Ray, String, or Funicular Polygon - The Chord Method		816-825	10		
	29.8 Graphical Differentiation - Ray Polygon - Tangent Method					
	29.9 Area Law					
	29.10 Graphical Differentiation - Area Law					
	29.11 Practical Applications - Differentiation					
	29.12 The Integral Calculus					
	29.13 Graphical Solution - Area Law					
	29.14 Graphical Solution - Funicular Polygon Method					
	29.15 Ordinate Scale of Integral Curve					
	29.16 Constants of Integration					
	29.17 Semigraphical Integration					
	29.18 Integration - Mechanical Method					
	29.19Practical Applications of Integration					
Total Number of Pages				13		16

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 = 949 - 13 = 936 pages

Volume (Pages Excluding Sections with Calculus Skills) =

Total Number of Pages - Number of Pages of Sections with Calculus Skills = 949 - 16 = 933

Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 30 - 1 = 29 chapters

Number of Sections = Total Number of Sections - Number of Sections with Calculus Skills = 695 - 17 = 678 sections

Statistical Summary

Total Number of Pages Covered by Text
(Excluding "Index"): 949

Total Numbers of Chapters and Sections:
30, 695

Percentage of Pre-Calculus Chapters

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

$$= \left(\frac{29}{30}\right)(100\%) = 96.7\%$$

Percentage of Pre-Calculus Sections

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

$$= \left(\frac{678}{695}\right)(100\%) = 97.6\%$$

Average Percentage of Pre-Calculus Content

$$\%_{\substack{\text{Pre-Calculu}\\ \text{Content}}} = \frac{\%_{\substack{\text{Pre-Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{96.7\% + 97.6\%}{2} = 97.2\%$$

Percentage of Chapters with Calculus Sections

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

$$= \left(\frac{1}{30}\right)(100\%) = 3.3\%$$

Percentage of Sections with Calculus Skills

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

$$= \left(\frac{17}{695}\right)(100\%) = 2.4\%$$

Average Percentage of Calculus Content

$$\%_{\substack{\text{Calculus}\\ \text{Content}}} = \frac{\%_{\substack{\text{Calculus}\\ \text{Chapters}}} + \%_{\substack{\text{Pre-Calculus}\\ \text{Sections}}}}{2} = \frac{3.3\% + 2.4\%}{2} = 2.9\%$$

Total Number of Chapters with Pre-calculus Mathematics Skills: 29 out of 30 **Total Number of Sections with both Pre-calculus and Calculus Mathematics Skills:** 678 out of 695	**Total Number of Pages with Pre-Calculus Skills Only:** 936 out of 949
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{936}{949}\right)(100\%) = 98.6\%$	

Conclusion on the Textbook:

(1) This textbook is one of the most popular before the widespread use of CADD software programs; and it is a great source of reference on manual drafting techniques.
(2) The mathematics concepts and skills needed for the reading and homework assignments across all Chapters except Chapter 29 (Graphical Mathematics) are all at pre-calculus level.
(3) Chapter 29 (Graphical Mathematics) involve concepts of beginning calculus such as [first integral] and [first derivative] and teaches graphical methods to solve beginning calculus methods.
(4) Chapter 25 (Graphical Vector Analysis) graphical techniques used to solve engineering analytic and predictive problems in statics,

Table 2F. Statistic on Textbook 6 (Applied Descriptive Geometry, 2nd Edition by Kathryn Holliday-Darr)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			**Page Information**	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[systems of units], [fraction], [scale], [angle], [square root], [power], [perpendicularity], [parallelism], [coordinates] (axes, planes, origin), [measurement] (length, width, height), [point], [space], [vertex]	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 = 473 - 0 = 473 pages Number of Chapters = Total Number of Chapters - Number of Chapters with Calculus Skills = 11 - 0 = 11 chapters				

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 473	**Total Numbers of Chapters and Sections:** 11, 50
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{50}{50}\right)(100\%) = 100\%$	**Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sectionss with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{0}{50}\right)(100\%) = 0\%$
Total Numbers of Chapters with Pre-Calculus Skills Only: 11 out of 11	**Total Number of Pages with Pre-Calculus Skills Only:** 473 out of 473
Percentage of Pre-Calculus Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{473}{473}\right)(100\%) = 100\%$	

Conclusion on the Textbook:

(1) This textbook offers detailed instructions on solving descriptive geometry problems.
(2) The mathematics concepts and skills needed for the reading and homework assignment are all at pre-calculus level.

Table 2G. Statistic on Textbook 7 (Basic Blueprint Reading and Sketching, 7th Edition, by C. Thomas Olivo and Thomas P. Olivo)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			**Page Information**	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[systems of units], [fraction], [scale], [angle], [square root], [power], [perpendicularity], [parallelism], [coordinates]	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 = 218 - 4 = 218 pages
Number of Sections = Total Number of Sections – Number of Sections with Calculus Skills = 14 – 1 = 14 sections

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 218	**Total Numbers of Sections and Units:** 14, 44
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{14}{14}\right)(100\%) = 99.3\%$	**Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sections with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{0}{14}\right)(100\%) = 0\%$
Total Number of Sections with Pre-calculus Mathematics Skills: 14 out of 14 **Total Number of Sections with both Pre-calculus and Calculus Mathematics Skills:** 0 out of 14	**Total Number of Pages with Pre-Calculus Skills Only:** 218 out of 218

Percentage of Pre-Calculus Only Volume:

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{218}{218}\right)(100\%) = 100\%$$

Conclusion on the Textbook:

(1) This textbook has been used at Santa Ana College and other colleges for engineering graphics courses.
(2) After careful examination of all pages of this voluminous textbook (218 pages total), it has been determined that the mathematics concepts and skills needed for the reading assignment are, as expected, all at pre-calculus level.

Table 2H. Statistic on Textbook 8 (Fundamentals of Geometric Dimensioning and Tolerancing, by Alex Krulikowski)

Pre-Calculus Level Concepts and Skills Found in All Chapters/Sections			**Page Information**	
Mathematics	**Physics**	**Chemistry**	**Page Numbers**	**Number of Pages**
[four operations], [geometric solids] (cylinder, sphere, cube), [geometric shapes] (circle, square, rectangle), [surface], [plane]	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 = 218 - 4 = 218 pages
Number of Sections = Total Number of Sections – Number of Sections with Calculus Skills = 112 – 0 = 112 sections

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 382	**Total Numbers of Chapters and Sections:** 12, 112
Percentage of Pre-Calculus Sections $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Sections}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{112}{112}\right)(100\%) = 100\%$	**Percentage of Sections with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Sections with Calculus Skills}}{\text{Total Number of Sections}}\right)(100\%)$ $= \left(\frac{0}{112}\right)(100\%) = 0\%$
Total Number of Chapters with Pre-calculus Mathematics Skills: 12 out of 12 **Total Number of Sections with both Pre-calculus and Calculus Mathematics Skills:** 0 out of 112	**Total Number of Pages with Pre-Calculus Skills Only:** 382 out of 382

Percentage of Pre-Calculus Only Volume:

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{382}{382}\right)(100\%) = 100\%$$

Conclusion on the Textbook:

(1) This textbook is one of the best textbooks on the subject of GD&T; and it has been used at Santa Ana College in California and in many other colleges.
(2) The mathematics concepts and skills needed for the reading and homework assignment are all at pre-calculus level.
(3) They could be taught or reviewed when the GD&T knowledge content and skills are included in a middle-school level engineering graphics course.

Table 2J. Statistic on Textbook 9 (A Comprehensive Introduction to SolidWorks 2011, by Godfrey Onwubolu)

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], [measurement and dimension] (length, width, depth, radius, diameter, angle), [systems of units], [angle] (right, acute and obtuse], [line] (straight, horizontal, vertical, curved, oblique, slanted, parabola, spline, helix, spiral), [plane], [axis], [point], [direction], [coordinates], [solid] (cylinder, sphere. prism, cube, wedge, loft, swept), [shape] (square, rectangle, circle, ellipse, polygon), [perpendicularity], [parallelism], [tangency], [array] (circular and rectangle), [view] (front, side, back, top, bottom, auxiliary), [axonometric] (isometric, dimetric, trimetric), [chamfer], [fillet], [mirror image]	N/A	N/A	N/A	N/A
Calculus Level Mathematics				
Concepts and Skills	**Chapters/Sections**			
N/A	N/A		N/A	N/A
Chapters with Pre-Calculus Level Mathematics Concepts and Skills ONLY Volume = Total Number of Pages – Number of Pages with Calculus Skills = 802 - 4 = 802 pages Number of Chapters = Total Number of Chapters – Number of Chapters with Calculus Skills = 26 – 0 = 26 Chapters				
Statistical Summary				
Total Number of Pages Covered by Text (Excluding "Index"): 802		**Total Numbers of Chapters:** 26		
Percentage of Pre-Calculus Chapters $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%)$ $= \left(\frac{26}{26}\right)(100\%) = 100\%$		**Percentage of Chapters with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Chapters with Calculus Skills}}{\text{Total Number of Chapters}}\right)(100\%)$ $= \left(\frac{0}{26}\right)(100\%) = 0\%$		
Total Number of Chapters with Pre-calculus Mathematics Skills: 26 out of 26 **Total Number of Chapters with both Pre-calculus and Calculus Mathematics Skills:** 0 out of 26		**Total Number of Pages with Pre-Calculus Skills Only:** 802 out of 802		
Percentage of Pre-Calculus Only Volume: $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{802}{802}\right)(100\%) = 100\%$				

Conclusion on the Textbook:

(1) Schroff Development Corporation is a publisher of textbooks on CADD software programs, including SolidWorks, AutoCAD, Inventor, 3ds MAX, Revit, CATIA and many others.

(2) The mathematics concepts and skills, in particular, those from the subject of geometry, needed for reading and hands-on homework assignment are minimal.

(3) Only in Chapter 7 (Part Modeling with Equation Driven Curves) (pages 7-8, 7-12, 7-15, 7-17 and 7-22) are basic calculus-based mathematics formulas such as [first derivative] and [first integral] appear in the explanation of technical terms; however, they do not involve homework assignment and thus, for all practical purposes, could be just ignored.

Table 2K. Statistic on Textbook 10 (Official Guide to Certified SolidWorks Associate Exams: CSWA, CSDA, CSWSA-FEA SolidWorks 2012-2013, by David C. Planchard)

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], [measurement and dimension] (length, width, depth, radius, diameter, angle), [systems of units], [angle] (right, acute and obtuse], [line] (straight, horizontal, vertical, curved, oblique, slanted, parabola, spline, helix, spiral), [plane], [axis], [point], [direction], [coordinates], [solid] (cylinder, sphere. prism, cube, wedge, loft, swept), [shape] (square, rectangle, circle, ellipse, polygon), [perpendicularity], [parallelism], [tangency], [array] (circular and rectangle), [view] (front, side, back, top, bottom, auxiliary), [axonometric] (isometric, dimetric, trimetric), [chamfer], [fillet], [mirror image]	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 = 218 - 4 = 218 pages
Number of Sections = Total Number of Sections – Number of Sections with Calculus Skills = 7 – 0 = 7 sections

Statistical Summary

Total Number of Pages Covered by Text (Excluding "Index"): 218	Total Numbers of Chapters: 7
Percentage of Pre-Calculus Chapters $\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Chapters}}{\text{Total Number of Chapters}}\right)(100\%) = \left(\frac{7}{7}\right)(100\%) = 100\%$	**Percentage of Chapters with Calculus Skills** $\%_{\text{Calculus}} = \left(\frac{\text{Number of Chapters with Calculus Skills}}{\text{Total Number of Chapters}}\right)(100\%) = \left(\frac{0}{7}\right)(100\%) = 0\%$
Total Number of Chapters with Pre-calculus Mathematics Skills: 7 out of 7 **Total Number of Chapters with both Pre-calculus and Calculus Mathematics Skills:** 0 out of 7	**Total Number of Pages with Pre-Calculus Skills Only:** 218 out of 218

Percentage of Pre-Calculus Only Volume:

$$\%_{\text{Pre-Calculus}} = \left(\frac{\text{Number of Pre-Calculus Pages}}{\text{Total Number of Pages}}\right)(100\%) = \left(\frac{218}{218}\right)(100\%) = 100\%$$

Conclusion on the Textbook:

After a careful and thorough examination of all pages of this manual, it has been concluded that the mathematics concepts and skills, in particular, those from the subject of geometry, needed for reading and hands-on homework assignment are minimal; they are all at pre-calculus level and do not exceed those found in Textbook 5 (*A Comprehensive Introduction to SolidWorks 2011*, written by Godfrey Onwubolu).

Table 2L. Statistic on Textbook 11 (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
(Excluding "Index"): 1049

Total Numbers of Chapters and Sections:
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.

Conclusions and Recommendations

This report has presented (1) information about eleven college-level engineering graphics, CADD and product 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 2L). The following are recommended: engineering graphic and CADD programs have been taught in many high schools and even middle schools across the United States; real-world product 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.

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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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