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WORKING FOR AN INNOVATION DEAL USA IN THE 21ST CENTURY
TRABAJANDO POR UN TRATO DE INOVACIÓN EEUU EN EL SIGLO XXI
为实现 21 世纪美国创新之政而奋斗

RESEARCH OUTCOMES

by Edward Locke (Gosingga-Daicin Mergen-Dasan Sakda)

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The Research Outcomes Section will host the web pages for the online publication of the outcomes of research on the determination of K-12 age-possible engineering knowledge content, i.e., selected topics of formula-based engineering analytic and predictive skills currently covered in college-level engineering textbooks, which require only the pre-calculus portions of mathematics, in the following majors or specialties and subjects:

- **Engineering Foundation**: Subjects covered under this Specialty are for all K12 students to be enrolled in the future engineering and technology programs, and they correspond to the engineering foundation courses in current lower-division engineering undergraduate programs. They include: (1) Introduction to STEAM & Product Design for K12, (2) Statics for K12, (3) Dynamics for K12, (4) Strength of Materials for K12, (5) Engineering Materials for K12, (6) Probability & Statistics for K12, and (7) Engineering Economics for K12.
- **Mechanical Engineering**: Subjects covered under this Specialty are for some K12 students to be enrolled in the future engineering and technology programs with an orientation towards a university majorin mechanical engineering, and they correspond to the mechanical engineering major courses in current lower- or upper-division engineering undergraduate programs. They include: (1) Mechanical Design for K12, (2) Fluid Mechanics for K12, and (3) Aerodynamics for K12, (4) Heat Transfer for K12, and (5) Thermodynamics for K12.
- **Engineering Technology**: Subjects covered under this Specialty are for some K12 students to be enrolled in the future engineering and technology programs with an orientation towards a university majorin mechanical engineering, engineering technology, or indudtrial technology, and they correspond to the relevant engineering major courses in current lower-division engineering undergraduate programs. They include: (1) Engineering Graphics, CADD & Product Design for K12, (2) Manufacturing Processes for K12, and (3) Engineering Programming for K12
- **Civil Engineering**: Subjects covered under this Specialty are for some K12 students to be enrolled in the future engineering and technology programs with an orientation towards a university majorin civil engineering or civil engineering related technology, or architectural design, and they correspond to the relevant engineering major courses in current lower-division engineering undergraduate programs. They include: (1) Introduction to Computerized Civil Engineering Design for K12, (2) Introduction to Global Positioning System and Land Surveying for K12, and (3) Introduction to Structural Design for K12.

- **Electrical Engineering**: Subjects covered under this Specialty are for some K12 students to be enrolled in the future engineering and technology programs with an orientation towards a university majorin electrical engineering, mechanical engineering or related technology, and they correspond to the relevant engineering major courses in current lower-division engineering undergraduate programs. They include: (1) Introduction to Electrical & Electronics Devices for K12, (2) Introduction to Circuit Analysis & Simulation for K12, (3) Introduction to Robotics & Programming for K12.

- **Capstone Engineering Design and Research:** This page lists recommended college-level textbooks to be used directly in Grade 12 Graduation Year Capstone Engineering Design and Research course, or as references for developing new instructional materials in this regard.
- **Available K12 STEAM Learning Resources:** This page hosts links to websites that offers useful information on engineering education, careers, professional and student organizations, K12 engineering and technology instructional materials, engineering design simulation software, and many others. They could be used in the Introduction to STEAM & Product Design for K12 and the **Capstone Engineering Design and Research** courses.
- **Mathematics Pre-requisites for Undergraduate Engineering Programs:** This page is dedicated to the analysis of mathematics pre-requisites, especially those at calculus level, needed for the completion of engineering major courses an science (physics and chemistry) courses included in typical college undergraduate engineering programs.
  The following page has been added on November 20, 2014:
  Recommended Artistic Skills for STEM Professionals: This page explores artistic skills useful for presentation of scientific, technological, engineering and mathematics concepts.

BASIC CONCLUSIONS FROM THE PREVIOUS RESEARCH

My previous research on the subjects of statics and fluid mechanics are encouraging in terms of the relationship between the engineering knowledge content from these two subjects, one at lower-division level, and the other at upper-division level, on the one side, and mathematics and science (physics and chemistry) pre-requisites on the other side. Based on this finding, we could make a hypothesis that with proper review of mathematics and science pre-requisites and with appropriate pedagogy, K12 students could have the potential to master a substantial amount of engineering knowledge content. Thus, it would be worthy to proceed with the research and subsequent pedagogic experiment.

(1) Mathematics pre-requisites: The most frequently needed mathematics skills to be reviewed or taught before teaching the pre-calculus portions of statics and fluid mechanics to 9th graders are listed in the table below. As readers might agree, they are very basic ones.

Topics to be Reviewed or Taught (From Larger to Smaller % of Occurrences for Both Subjects)		For Statics (13 Topics)		For Fluid Mechanics (19 Topics)		For Both Statics & Fluid Mechanics (23 Topics)	
		Number of Occurrences	%	Number of Occurrences	%	Number of Occurrences	%
1	four basic operations	28	32.2	74	37.4	102	35.8
2	exponent	6	6.9	31	15.7	37	13.0
3	areas of geometric shapes: circle, triangle, etc.	1	1.1	27	13.6	28	9.8
4	trigonometric functions	14	16.1	14	7.1	28	9.8
5	square root	4	4.6	16	8.1	20	7.0
6	coordinate system	15	17.2	1	0.5	16	5.6
7	sigma notation and summation	9	10.3	4	2.0	13	4.6
8	volume	0	0	9	4.5	9	3.2
9	geometry: point, axis/line, 3D body	5	5.7	0	0	5	1.8
10	ratio	0	0	4	2.0	4	1.4
11	unit conversion	1	1.1	3	1.5	4	1.4
12	graph	0	0	3	1.5	3	1.1
13	partial derivatives	0	0	3	1.5	3	1.1
14	triangle	0	0	3	1.5	3	1.1
15	height	0	0	2	1.0	2	0.7
16	cylinder	0	0	1	0.5	1	0.4
17	measurement: time	1	1.1	0	0	1	0.4
18	percent	1	1.1	0	0	1	0.4
19	perimeter	0	0	1	0.5	1	0.4
20	problem-solving	1	1.1	0	0	1	0.4
21	Pythagorean Theorem	0	0	1	0.5	1	0.4
22	radius	0	0	1	0.5	1	0.4
23	surface	1	1.1	0	0	1	0.4
Total Number of Occurrences		87	100	198	100	285	100

More challenging mathematics skills to be reviewed or taught before teaching the pre-calculus to beginning calculus portions of statics and fluid mechanics subjects to 9th graders include those listed on the table below.

Topics to be Reviewed or Taught as Special Lessons (From Larger to Smaller % of Occurrences for Both Subjects)		For Statics (7 Topics)		For Fluid Mechanics (7 Topics)		For Both Statics & Fluid Mechanics (13 Topics)	
		Number of Occurrences	%	Number of Occurrences	%	Number of Occurrences	%
1	integration	0	0	13	44.8	13	18.1
2	cross product	11	25.6	1	3.4	12	16.7
3	trigonometric functions	12	27.9	0	0	12	16.7
4	derivative	0	0	7	24.1	7	9.7
5	sigma notation and summation	7	16.3	0	0	7	9.7
6	dot product	6	14.0	0	0	6	8.3
7	vector graphics	4	9.3	0	0	4	5.6
8	logarithmic functions	0	0	3	10.3	3	4.2
9	analytic geometry	0	0	2	6.9	2	2.8
10	ellipse	0	0	2	6.9	2	2.8
11	linear algebra	2	4.7	0	0	2	2.8
12	analytic geometry: hyperbolic tangent	0	0	1	3.4	1	1.4
13	Parallelogram Law for the Addition of Force/Vector Graphics	1	2.3	0	0	1	1.4
Total Number of Occurrences		43	100	29	100	72	100

(2) Science (physics and chemistry) pre-requisites: The most frequently needed physics concepts to be reviewed before teaching the pre-calculus portions of statics and fluid mechanics to 9th graders are listed in the table below. As readers might agree, they are the very basic ones.

Topics to be Reviewed (From Larger to Smaller % of Occurrences for Both Subjects)		For Statics (7 Topics)		For Fluid Mechanics (18 Topics)		For Both Statics & Fluid Mechanics (22 Topics)	
		Number of Occurrences	%	Number of Occurrences	%	Number of Occurrences	%
1	velocity	0	0	41	21.6	41	18.6
2	density	0	0	36	18.9	36	16.3
3	force	16	51.6	18	9.5	34	15.4
4	gravity	0	0	31	16.3	31	14.0
5	speed	0	0	15	7.9	15	6.8
6	mass	0	0	14	7.4	14	6.3
7	temperature	0	0	8	4.2	8	3.6
8	Newton's 1st, 2nd and 3rd Laws	6	19.4	2	1.1	8	3.6
9	acceleration	2	6.5	3	1.6	5	2.3
10	momentum	0	0	5	2.6	5	2.3
11	energy	0	0	4	2.1	4	1.8
12	graph	0	0	3	1.6	3	1.4
13	motion	3	9.7	0	0	3	1.4
14	power	0	0	3	1.6	3	1.4
15	weight	0	0	3	1.6	3	1.4
16	lever	2	6.5	0	0	2	0.9
17	heat	0	0	1	0.5	1	0.5
18	molecule	0	0	1	0.5	1	0.5
19	Newton's Law of Gravitation	1	3.2	0	0	1	0.5
20	potential energy	0	0	1	0.5	1	0.5
21	scientific inquiry	1	3.2	0	0	1	0.5
22	work	0	0	1	0.5	1	0.5
Total Number of Occurrences		31	100	190		221	100

More challenging science (physics and chemistry skills to be reviewed or taught before teaching the pre-calculus to beginning calculus portions of statics and fluid mechanics subjects to 9th graders include those listed on the table below.

Topics to be Reviewed or Taught as Special Lessons (From Larger to Smaller % of Occurrences for Both Subjects)		For Statics (0 Topics)		For Fluid Mechanics (11 Topics)		For Both Statics & Fluid Mechanics (11 Topics)	
		Number of Occurrences	%	Number of Occurrences	%	Number of Occurrences	%
1	pressure	0	N/A	30	66.7	30	66. 7
2	friction	0	N/A	3	6.7	3	6. 7
3	{absolute temperature}	0	N/A	2	4.4	2	4.4
4	{Ideal Gas Law}	0	N/A	2	4.4	2	4.4
5	Newton's 1st, 2nd and 3rd Laws	0	N/A	2	4.4	2	4.4
6	{gas/liquid}	0	N/A	1	2.2	1	2.2
7	{molecular and intermolecular cohesive force}	0	N/A	1	2.2	1	2.2
8	Reynold Number	0	N/A	1	2.2	1	2.2
9	speed of sound	0	N/A	1	2.2	1	2.2
10	stress	0	N/A	1	2.2	1	2.2
11	torque	0	N/A	1	2.2	1	2.2
Total Number of Occurrences		0	N/A	45	100	45	100

Past experience in many places also indicates that K12 students are capable of learning and mastering analytic and predictive engineering knowledge and computational skills, beyond the "trial-and-error" approaches.

Australian experience: The table below shows a rough estimate of engineering analytic knowledge content tried at Australian high schools. On March 26, 2009, during the International Technology Education Association 2009 Annual Conference, in Louisville, Kentucky, two presenters from Australia, Peter Thompson and Ruth J. Thompson distributed an information CD on K-12 engineering education in Australia to the audience. Based on analysis of the files contained in the CD, I have compiled a report on K-12 engineering education in Australia, and made the following preliminary conclusions: (a) Engineering knowledge content: Compared to various models that exist in the United States, Australia's engineering analytic, predictive principles and skills are more extensively and rigorously incorporated into K-12 engineering curriculum. The curriculums tried in Australian high schools demonstrated clear and defined content knowledge standards. For example, Higher School Certificate Examinations and other evaluation instruments established by state government. However, the inclusion of engineering knowledge content at high school level is uneven with the exception of the subjects of material science and electronics/electricity. The estimated percentage is quite small compared to what could possibly be included in the engineering curriculum, as shown in the table below. Thus, the research outcomes and possible subsequent endeavors by the interested stakeholders in the United States may contribute to the development of an American model of K-12 engineering curriculum that could be competitive with respect to the established Australian model. (b) Engineering design abilities: The working prototypes, which are designed and fabricated by Australian students from 2003 and 2004 High School Certificate Programs featured as InTech 2004 and 2005 Outstanding Major Projects, display high qualities of creativity and practical functionality. (c) Experience to learn: Australia's experience with K-12 engineering education indicated that, those engineering topics that match high school students' cognitive developmental maturity, are "hands-on," and are well defined and "straightforward," with clear-cut "restrictions," have "worked;" and anything that exceeds high school students' cognitive maturity level, or is ill-defined "hasn't always worked," this includes exercises requiring a high level of mathematics ability such as truss analysis, or design challenges with little restriction such as Rube Goldberg machine. Based on this conclusion, we could see the need for defining what engineering topics are appropriate for K-12 students. The objective of this website is exactly to fulfill this practical need.

Subject of Engineering and Page Nos. in Edward Locke's Report (Locke, 2009d)	Rough Estimates of Engineering Knowledge Content Tried at High Schools in Australia, as a Percentage of Pre-Calculus Level Engineering Knowledge Content Found in College-level Engineering Textbooks
Statics (pp. 71 - 76)	15% - 20%
Dynamics (pp. 60 - 72)	10%
Strength of Materials (pp. 60 - 72)	10%
Material Science (pp. 60 - 72)	40% - 50%
Fluid Mechanics (pp. 60 - 72)	< 10%
Aerodynamics (pp. 60 - 72)	< 10%
Mechanical Design (pp. 60 - 72)	< 10%
Electronics/Electricity (pp. 60 - 72)	40% - 50%

APPLICATIONS OF THE RESEARCH OUTCOMES

Vision Paper Vision Paper The Research Outcomes, i.e., the initial and tentative selection of K12 age-possible engineering topics, published in this Section, could be used in the following situations:

(1) **The implementation of the Proposed Model for a Streamlined, Cohesive, and Optimized K-12 STEM Curriculum with a Focus on Engineering**: By supporting teachers, school administrators and community leaders, in pedagogic experiments leading towards the eventual development and publication of a comprehensive set of FREE online K12 engineering and technology textbooks or instructional modules, as "public domain" educational resources, to be used by K12 students in the United States and across all English-speaking Nations. This is the ultimate goal of the outcomes of this research, which could be gradually implemented through experiments and

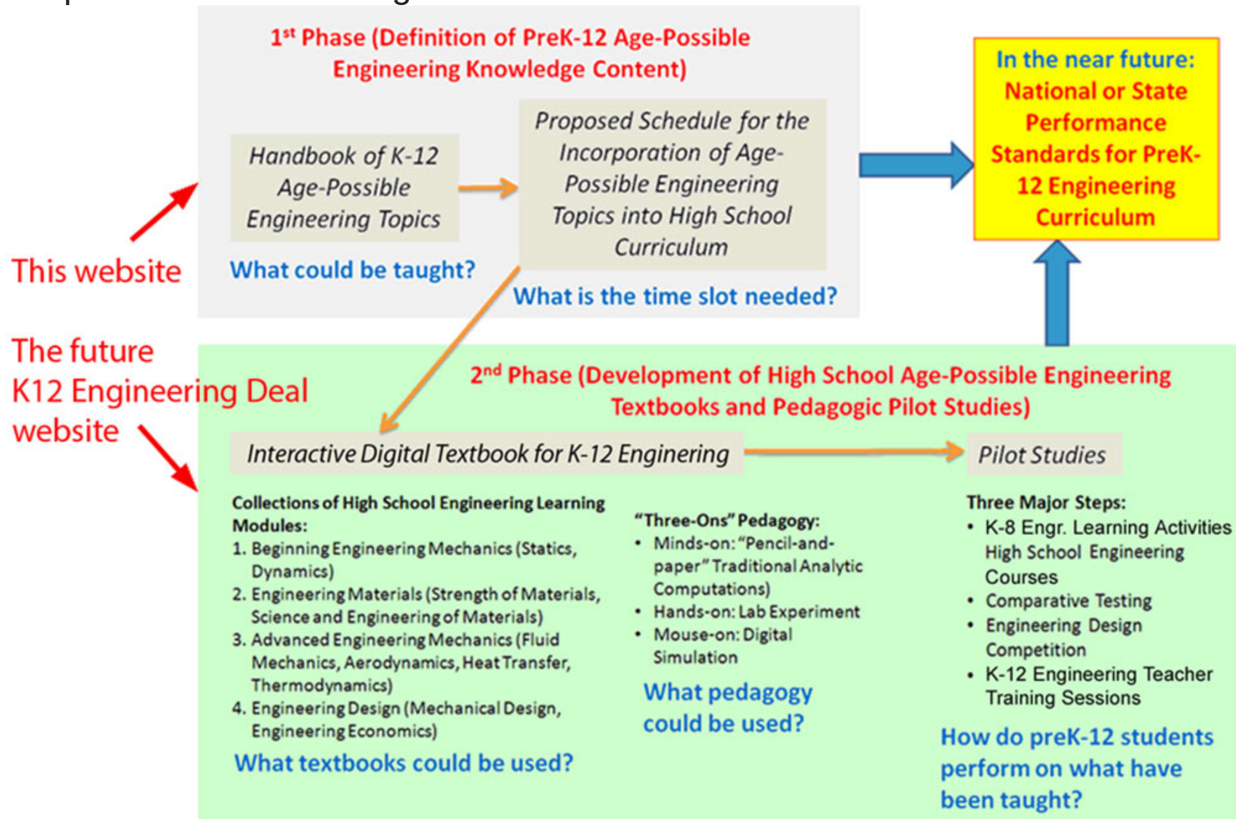
improvements, step-by-step, taking into consideration the pedagogic traditions of America's K-12 school systems, while pragmatically promoting meaningful changes that could help to maintain the leading position of the United States in STEAM education. This ultimate goal is clearly explained in the illustrations available on the Statement of Philosophy page of this website. It is ambitious and could be finally achieved by several rounds of pedagogic experiments, starting as "middle to high school elective courses" with a carefully selected set of the most relevant and important engineering topics from several subjects, as advised by Professor Jose Ramirez, Chair of the Department of Engineering and Technologies at East Los Angeles College. The above-mentioned pedagogic experiments are explained in the Guidelines for Pedagogic Experiments page of this website.

(2) **Reference resource for existing "project-based-learning" K12 engineering curriculum packages:** By other K12 engineering and technology curriculum developers as references in the inclusion of formula-based engineering computational skills into their existing "project-based-learning" curriculum and instructional materials. This is the part of the most immediate and recent goal of this research, which could help to solve the problems in the current practice of K-12 engineering education, as discussed in the authoritative 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, which included the absence of cohesive K-12 engineering curriculum and the lack of well-developed standards, issues that have been already addressed in the Vision Paper.

(3) **Reference resource for K12 mathematics and science teachers:** (a) By K12 school teachers of mathematics at all grades in the inclusion of engineering application problems as homework assignment to show students how mathematics skills work in the real world of design; everyone knows that without real world application, mathematics problems are "boring." (b) by high school teachers of physics and chemistry to show how relevant scientific principles are applied in the solution of real world engineering design problems. This is another part of the most recent and immediate goal of this research, which could help K-12 mathematics and science teachers to connect students to real-world problems.

(4) **Reference resource for college and university professors:** To offer a review of mathematics skills, physics and chemistry principles and concepts to students in engineering major courses at the start of the semester or quarter,

so as to help students succeed in the course with enhanced abilities to complete homework assignments. .



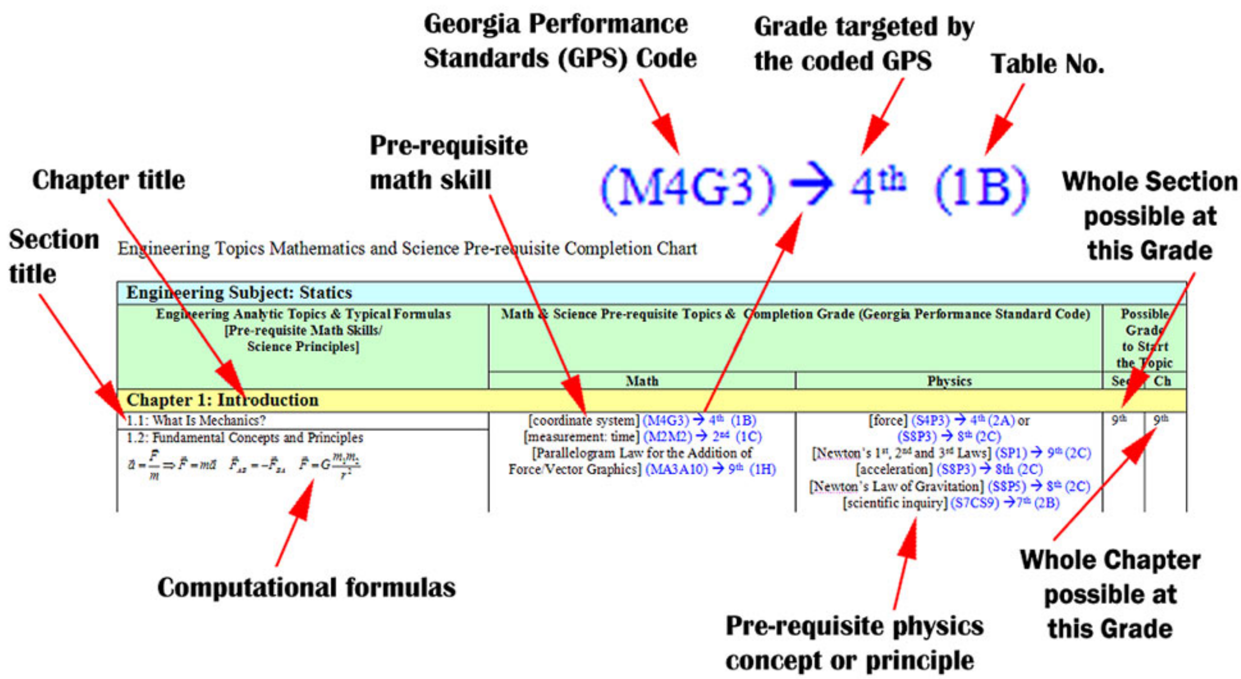
The PowerPoint slide above shows the two possible Phases of the SDCHLARSTEAM K12 Plus Project leading towards a possible eventual establishment of National or State Performance Standards for K12 Engineering Curriculum.

The First Phase is the Definition of K-12 Engineering Knowledge Content, i.e., what have been and will be published on the Research Outcome section of this website. This is designed to answer the question of "what are the engineering topics that could possibly be taught to K-12 students at various grade levels, based on the students' prior mastery of mathematics skills and science principles (notably physics and chemistry) defined by the mandates of national and/or state math and science performance standards with consideration for the actual performance outcomes of average students?" The documents published in the Research Outcomes section of this website could be used as references in the Second Phase of the implementation of the SCHOLAR STEAM K12 Plus Project, in the selection of relevant chapters or sections from existing college-level engineering textbooks to be used in K12 pedagogic experiment, and in the eventual development of K12 age-appropriate online engineering textbooks and other instructional materials. The Second Phase is aimed at answering the questions of "to what degree could high school students master selected pre-calculus level engineering topics which up to this point, are taught only to college engineering students?" Notice that the various subjects of engineering from the Engineering Foundation, Mechanical Engineering and Capstone Engineering Design and Research categories have been organized into Four Collections of High School Engineering Learning Modules: (1) Beginning Engineering Mechanics (Statics, Dynamics), (2) Engineering Materials (Strength of Materials, Science and Engineering of Materials), (3) Advanced Engineering Mechanics (Fluid Mechanics, Aerodynamics, Heat Transfer, Thermodynamics), and (4) Engineering Design (Mechanical Design, Engineering Economics), with advice from East Los Angeles College Engineering and Technologies Department faculty, i.e., Professors Jose Ramirez, Kamyar Khashayar, Artin Davidian, Humberto Gallegos, and Brian Vasquez. The above Four Collections constitute a high school counterpart of a typical college undergraduate mechanical engineering program, or a High School Mechanical Engineering Pathway. Among the above Four Collections, the first one is applicable to all other Pathways, in civil and electrical engineering fields.

THE CONCEPTUAL FRAMEWORK USED IN THE INITIAL DETERMINATION OF K12 AGE-POSSIBLE ENGINEERING KNOWLEDGE CONTENT

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 explored in the Vision Paper (pp. 26-27) includes the following step as illustrated in the picture below: **(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.

The original research data table used to initially determine high school 9th Grade age-possible statics topics is shown in the picture below.



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.

RESEARCH OUTCOMES Navigator:

(1) **Engineering Foundation** (Introduction to STEAM for K12, Statics for K12, Dynamics for K12, Strength of Materials for K12, Engineering Materials for K12, Statistics& Probabilities for K12, and Engineering Economics for K12);
(2) **Mechanical Engineering** (Mechanical Design for K12, Fluid Mechanics for K12, Aerodynamics for K12, Heat Transfer for K12, Thermodynamics for K12);
(3) **Engineering Technology** (CADD& Product Design for K12, Manufacturing Processes for K12, Engineering Programming for K12);
(4) **Civil Engineering** (Introduction to Computerized Civil Engineering Design for K12, Introduction to Global Positioning System & Land Surveying for K12, Introduction to Structural Design for K12);
(5) **Electrical Engineering** (Introduction to Electrical & Electronics Devices for K12, Introduction to Circuit Analysis & Simulation for K12, Introduction to Robotics & Programming for K12);
(6) **Capstone Engineering Design and Research**;
(7) **Available K12 STEAM Learning Resources**;
(8) **Mathematics Pre-requisites for Undergraduate Engineering Programs**;
(9) **Recommended Artistic Skills for STEM Professionals**.

Freedom and opportunities! You will have the right to a high quality K12 science, technology, engineering, arts and mathematics (STEAM) education!

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自由和机会！你们将拥有接受高质量的、贯穿幼儿园到中小学阶段的科学、技术、工程、艺术和数学教育的权利！