Rationale: Teaching and Learning of Mathematics in the 21st Century

September 2019

Mathematics in the Age of "Ask Google"

As we are well into the 21st century and quickly approaching the quarter century mark, educators have to ask the essential question, in the age of Ask Google, what could and should education look like, feel like, and achieve. For mathematicians, the question is even more daunting as we try to parse out and understand what needs to be taught for understanding, how is conceptual understanding conveyed, and what is the role of applied mathematics. These questions become salient as it becomes more and more apparent that Google can solve fractions, decimals, and percent. There are algebra and quadratic calculators online (https://www.mathpapa.com/quadratic-formula/). There are even online programs that "show the work"; an example is WolframAlpha (https://www.wolframalpha.com/).
As students become more and more computer literate, more and more able to solve for "x" by asking Google, it is incumbent upon educators to re-conceptualize what is meant by the mathematics standards, what does mathematics teaching look like, and what is it that we want students to learn and understand. We need to discuss how we ensure that students walk away from a basic education with numeracy skills that will serve them for careers that are not yet defined, developed, or even invented.

In dealing with a world that is rapidly changing, technologically, robotically and globally, the jobs of the future that we are preparing our students for are non-existent today and may or may not be well defined when students leave their traditional schooling years (Blair & Getz 2011).

What should be our focus, as educators, as mathematicians, and as stewards of the public good, to ensure that we adequately prepare students? How do we play to the students' strengths to ensure they have the necessary skills to propel them into meaningful and productive lives? What is the essence of a basic education as we hit the quarter century mark? The half-century mark? Or even the next century mark?

These questions, and many more, are the ones that educators need to grapple with as we define what is education for the 21st century in the age of "*Ask Google*"? Especially in mathematics, where we are still following a very traditional pipeline, one that needs to be reexamined and reconsidered as we work to develop individuals for lives and careers that are dynamic and ever changing.

Currently, there is one traditional pathway that must serve most students and a perceived readiness gap when students do not perform well on that pathway.

Bridging the College Readiness Mathematics Gap

The gap in college readiness for mathematics has plagued American educational systems for more than a millennium or since the beginning of time (Burdman 2018; Byum, Irvin, & Bell 2015; Gao 2016). In fact, there is no time in American educational history when the issues of mathematics achievement have not been a concern, especially for underrepresented youth. Students who are poor, African-American, Native Americans or Latinx have always shown achievement gaps in the areas of mathematics and science. Additionally, women have also lagged behind men in the STEM fields as has been documented in the various studies (Long, Iatarola, & Conger 2009).

Here are some of the many reasons for the gaps: a misalignment between what high schools require and what colleges and universities expect; the lack of coherence between the high school curriculum and college expectations; the impact of excessive testing in high school and the effect on instructional strategies; the over-reliance on procedures in mathematics with scant attention to conceptual understanding; concerns about tracking students into lower paying careers; and the lack of content preparation for PK-12 instructors at both the elementary and secondary levels.

This paper offers a number of suggestions, for both high schools and colleges to consider, as they work on addressing the college readiness gap and creating more salient student success pathways.

The High School Gap Year(s)

One issue to address when looking at academic preparation for college level work is high school readiness and what it takes to leave high school ready for the rigors of mathematics at the college level. Currently, many states require two years of mathematics for high school graduation (2012) and three years of mathematics for university admissions. This mismatch between high school graduation requirements and college entrance requirements opens the door to student tracking and creates an unlevel playing field. For parents and communities that are not aware, this mismatch is not always apparent. Additionally, research indicates that 4 years of mathematics lead to stronger skills, better conceptual understanding, and a wider array of options available upon graduation (ACT 2007; Long, Iatarola, & Conger 2009; Washington, DC: Hart Research Associates 2011).

Moreover, there is strong evidence that a gap year or two leads to remedial courses at the university, since the strongest predictor of mathematics success at the university is that the students are in the "next" course in the sequence, no matter what that course is. Admittedly, these studies are of students who take a traditional pathway and are successful, but the data is clear that even for good students, being away from mathematics for a year or two is not in the best interest of a timely college graduation (Achieve 2013; Burdman 2018; Byum, Irvin, & Bell 2015; Gao 2016).

However, given the different interests and career trajectories that students are beginning to undertake, it may be prudent to not have ALL students embark on the traditional course of mathematics study, especially if they have decided they do not need a mathematics intensive major. Indeed, opening up the possibilities that there are many paths to successful mathematics education could be one of the innovations needed to address fundamental educational needs for the 21st century.

High School Readiness: Senior Year Mathematics Experience

A potential solution for these issues and concerns for academic preparation is to consider a senior year mathematics experience that is dependent on student interests and helps maintain the widest array of post-secondary options open for students. It is referred to a senior year mathematics experience because it branches from the traditional experience of Algebra I, Geometry, Algebra II, Pre-calculus (Mathematical Analysis/Trigonometry) and Calculus to suggesting that there be more options depending on student needs, strengths, goals, and interests. Although this list is not exhaustive, here are four possible student profiles to address with the various pathways:

1. For students who intend to pursue a STEM field, a traditional recommendation is in order. A calculus or pre-calculus course supports the goals they have set for themselves.
2. For students who are going to major in art, music, history, philosophy or any other similar major, a suggestion could be that they take an advanced quantitative reasoning or statistics course to enhance their reasoning skills with a quantitative focus. These courses could include computer science, engineering, data science, business finance etc.
3. For students who are certain they want to study the social sciences, psychology, economics, sociology, political science, etc., a plausible recommendation would be to take either an advanced quantitative reasoning course or a statistics course during their senior year.
4. For students who are undecided, or are not prepared for college level mathematics by their senior year in high school, a recommendation to take a rigorous transition to college mathematics course is supported by the research (Boatman 2012; Logue, Watanabe-Rose, Douglas 2016).

These senior year mathematics experiences go a long way toward helping students be academically prepared upon leaving high school and specializing in their area of interest beginning in the senior year of high school. This would have a twofold effect, allow students to diversify their mathematics pathway based on interest and keep STEM options open throughout most of the high school career.

Potential Pathways

PATHWAY	COURSES
STEM Pathway	Algebra 1 Geometry Algebra 2 or its equivalent Mathematical Analysis/Trigonometry/Pre-Calculus Calculus (Dual Credit or AP)
Statistics	Algebra 1 Geometry Algebra 2 or its equivalent Statistics (Dual Credit or AP)
Quantitative Reasoning	Algebra 1 Geometry Algebra 2 or its equivalent

	Advanced Quantitative Reasoning (Dual Credit or AP)
Other Options	Transition to College Mathematics Course (post Algebra 2 or its equivalent)

Courses that Support a Variety of Pathways

ALGEBRA 2 EQUIVALENT

In order to enhance the senior year mathematics experience and serve the needs of ALL students prepared to enroll in Algebra 2, high schools should offer an Algebra 2 equivalent course that advances both college and career readiness along a calculus, quantitative reasoning, or statistical reasoning pathway. Algebra 2 equivalent courses should require successful completion of Algebra 1, and address a variety of mathematical topics for success in a career or entry-level collegiate pathway. In an Algebra 2 equivalent course, students connect and use the strands of reasoning with functions, data exploration and statistical reasoning, probability and number sense, and proportional reasoning to model situations within meaningful contexts.

TRANSITION TO COLLEGE MATHEMATICS

A transition to college mathematics course is appropriate for 12th grade students who are undecided about their career, or whose academic performance prior to 12th grade indicates that they are not yet prepared to succeed in a gateway-level college mathematics course. The goal of a transition course is to develop students' quantitative and algebraic reasoning abilities, as well as to develop and strengthen social-emotional skills and competencies critical to academic and life success, thus preparing them for success in a variety of different gateway-level mathematics courses and careers, including STEM.

High School Offerings

While many of these options may resonate with educators, there still will be others who will have lots of questions. Some questions may be on the efficacy of having too many options in the senior year, how the master schedule will handle it, how schools will find enough qualified teachers, how teacher preparation programs will produce enough qualified teachers, and even how can students fit it in when they need to work. This is when we need to remember that we are in the 21st century and education does not need to be a teacher in front of a classroom of 30 to 50 students for 45 to 90 minutes at a time. We can put our minds together and get creative about different ways of organizing content, delivering the curriculum, and flexible scheduling so students can have their academic needs met in a timely, efficient, and effective manner.

As high schools are working toward a 21st century curriculum and supporting students' academic preparation, the **attached rubric** and be a helpful guide in determining where your school stands in providing strong academic preparation for students to be college and career ready and what other steps your school can take to ensure excellent academic preparation.

In this rubric, we have schools examine five areas: 1) curriculum, 2) instruction, 3) in-school collaboration, 4) community involvement, and 5) family involvement. A high school can rate itself on these various measures to ascertain their strengths and areas for improvement as they determine if they are offering courses, pathways, and options to help high school students be prepared for a wide array of options upon completing high school.

Student Ready Colleges: Pathways to Success

Helping students be successful in the latter half of the 21st century requires colleges and universities to shift from solely requiring college readiness towards becoming a *Student Ready* institution. It is evident from the literature that students will come to college prepared differentially regardless of what type of preparation they have had in high school. Irrespective of everything the high school has done to help students be prepared for the rigors of college, many students will need varying levels of support to be successful (Adelman 2005; Bozick, Ingels, & Owings (2008); Finkelstein, Fong, Tiffany-Morales, Shields, & Huang 2012; Rose & Betts 2001).

We are defining a student ready college as a college or university that has created the systems and structures that will allow the greatest diversity of students to be successful at their chosen major, career, or field. IHEs that have designed programs, curricula, and pathways to success for the myriad of students who arrive at their campus will be ready to instruct successfully all students who come to their campus.

In the area of mathematics, once students move onto a two-year college or a four-year university, there needs to be an emphasis on student ready mathematics pathways to success. As long as students successfully completed a rigorous academic preparation course of study, they should be able to enter the university college ready but might need varying levels of support to be successful. The support can come in the form of a co-requisite course, or student support services offered by various campus entities (Boatman 2012; Logue, Watanabe-Rose, Douglas 2016).

The designs of pathways to success must have students' needs, interests, and goals in mind. Not all students will need to pass a college algebra course for success and not all students will be able to pass a statistics course without some support. The table below shows various options that student ready IHE's could have in place for college success:

GATEWAY LEVEL COURSES	GATEWAY LEVEL COURSES WITH SUPPORT
College Algebra or Pre-Calculus	Co-Requisite College Algebra or Pre-Calculus Co-mingled/Cohort
Quantitative Reasoning	Co-Requisite Quantitative Reasoning Co-mingled/Cohort
Introductory Statistics	Co-Requisite Introductory Statistics Co-mingled/Cohort

Creating these pathways to success requires IHEs to have a number of structures and systems in place that have been shown to increase student success and decrease the time to degree (White 2016). The more of these support systems an IHE can provide in wrap-around services, the greater the likelihood of student success. Clearly any of these structures is better than none, but none of them stands alone as the sole reason for student success. They create an integrated and interrelated holistic web of success for students.

We have identified systems in areas like curriculum, instruction, student support, collaboration, community and family involvement, and opportunities. The rubrics created are categorized according to PreK-12 and Post-Secondary. A PreK-12 institution may employ the rubric to verify what system it has in place to help students get prepared for college and career, while at the same time an IHE can use the attached rubric to see what the strengths and challenges that currently exist in their system as a way of helping to increase graduation and persistence rates and decrease time to degree.

The rubric is not exhaustive and was created by basically give higher education a perspective of what makes a campus not only be ready for the students but also be cognizant of its limitations in doing so. Of course, these measures may be adjusted as needed, as some categories may be deemed necessary to be added or deleted, or even revised. See Appendix B.

Multiple Measures Placement and Appropriate Co-requisite Support Courses

Central to the idea of student ready colleges are structures that enable students to complete their gateway level mathematics course within their first year of college. Completion of a gateway mathematics course in the first year increases the chances that a student will complete a degree or certificate (Jenkins, 2017), and when combined with appropriate alignment, creates coherent gateway mathematics courses that empower students to utilize mathematics in their careers and lives. Structures that support students in completing their gateway level mathematics course in the first year include two main components, 1) utilizing multiple measures to more accurately assess whether a student will be successful in their gateway level mathematics course, and 2) utilizing co-requisite support courses to adequately prepare students deemed underprepared.

Relying solely on mathematics placement tests to determine if students are college ready is, at best, problematic, and places many students that would otherwise thrive at the college level in developmental education (Scott-Clayton, 2015). Student ready institutions can counter this by using a combination of measures, including high school GPA, non-cognitive assessments, and career inventories to best place diverse student groups. Once a student has been deemed underprepared, college ready institutions may enroll the student in a gateway level mathematics course, and provide support through a co-requisite support course. This eliminates transition points that create barriers to gateway level completion, and increases the chances that students will persist.

Best practice in the design of co-requisite support courses requires student ready institutions to think carefully about the content taught in the co-requisite support course. To prepare students adequately for success in their gateway level mathematics course, a deep connection between the gateway course and the co-requisite support course should be established. *Backmapping* from the gateway level course to determine the content of the co-requisite support course creates coherence between the courses, and requires institutions to shift away from arbitrarily requiring content typically found in beginning or intermediate algebra unless students intend to take calculus. This connection may be enhanced further by creating joint calendars that connect the material in the co-requisite support course to the material in gateway course.

Conclusion

The high school curriculum has long been a product of tradition, and many efforts have been tried and done to update it. Changes ranging from the curriculum to the instruction to the assessment abound, and yet mathematics has maintained itself as the gatekeeper of students' success. What we propose here is the restructuring of pathways for the students. The current pathways, particularly the STEM pathways, do not serve our students best. Many get lost in the system and therefore, avoid STEM at all cost. Students need to be given the real support they need while enrolled in these courses. Further, understanding the contemporary needs of our students is paramount. What traditionally was working on them do not necessarily will work this time.

Pathways to college, STEM, career and even to success need to be revisited and restructured. More and more students need this change. Inter-segmental parties need to be involved in the communication, design and implementation of these modifications. Now is the best time to do it.

Appendix A: Some Data

- **HS mathematics requirements:**
    - → 18 states require 4 years of mathematics
    - → 25 states require 3 years of mathematics
    - → 2 states require 2 years of mathematics
    - → 5 states have district level policies

- **State University requirements:**
    - → 16 states require 4 years of mathematics
    - → 1 state requires 3 ½ years of mathematics
    - → 26 states require 3 years of mathematics
    - → 1 state requires 2 years of mathematics
    - → 7 states have no requirement

- **In 2017, 66.7% of high school graduates enrolled in college**
    - → 22.6% in 2-year colleges
    - → 44.2% in 4-year colleges

- **ACT**
    - → Benchmark for Mathematics is 22
    - → Testing percentages vary from 7 - 100% of graduating seniors
    - → Percentages of students meeting the benchmark vary from 21 - 74%
    - → Of states that tested >50% of grads
        - Highest % of students meeting benchmark - SD 49%
    - → Of states that tested >80% of grads
        - Highest % of students meeting benchmark - MN 47%

- **SAT**
    - → Benchmark for Mathematics is 530
    - → Testing percentages vary from 2 - 100% of graduating seniors
    - → Percentages of students meeting the benchmark vary from 29 - 88%
    - → Of states that tested >50% of grads
        - Highest % of students meeting benchmark - VT 61%
    - → Of states that tested >80% of grads
        - Highest % of students meeting benchmark - NH 46%

Appendix B: Members

Dr. Zee Cline is the Statewide Director of the California Academic Partnership Program (CAPP). CAPP is an intersegmental program working with the three segments of higher education and the K-12 system. Under Dr. Cline's leadership, CAPP has launched two grants: the CAPP Demonstration Project, which helps schools build post-secondary partnerships, and College Going Culture Grant, which helps schools develop a college-going culture. CAPP is also responsible for the Mathematics Diagnostic Testing Project, an intersegmental collaborative effort that has been developing diagnostic tests for more than 30 years. Prior to joining the Chancellor's Office, Dr. Cline was a professor at CSU San Marcos.

Rebecca Davenport is a faculty member of Western Governors University in their teacher preparation program. She always focused in helping pre-service teachers. She is interested in learning and understanding what is needed in today's classroom and also in helping to change current instruction to facilitate developing the next generation of teaching.

Maria McClain is a Math Teacher and Department Chair at Deer Valley High School in the Antioch Unified School District. She also serves as a National Science Teaching Association/National Council of Teachers of Mathematics STEM Teacher Ambassador, and is a member of the California C3R State Intervention Advisory Board and Task Force and the100Kin10 Teacher Forum. Maria's awards include Antioch Unified School District Teacher of the year, Contra Costa County Teacher of the Year, California State Teacher of the Year Semi-Finalist, and recipient of a Presidential Award for Excellence in Mathematics and Science Teaching (PAEMST award). Maria is National Board Certified in adolescence and young adulthood mathematics and holds a BA in Mathematics from California State University, Sacramento.

Dr. Lilian Metlitzky is currently leading a regional team to develop and implement a transitional high school mathematics course that will prepare students for college-level mathematics and entry into STEM pathways. This work involves curriculum development, professional learning, and statewide dissemination. As a CSU mathematics professor for almost 40 years, her professional efforts have been devoted to bridging the gap between high school student preparation and post-secondary expectations for proficiency in mathematics. This has involved leading local and statewide efforts to improve mathematics education throughout the pipeline, including high schools, community colleges, universities, teacher preparation and teacher inservice.

Elena Quiroz-Livanis is the Chief of Staff and Director of Academic Policy and Student Success, Massachusetts Department of Higher Education.

Frank Savina leads the design, development, and implementation of the pathway to Calculus for the Dana Center Mathematics Pathways, a transformative redesign to modernize entry-level college mathematics programs through working with states, systems, universities, and colleges. Frank has more than 20 years of teaching experience at the university and high school levels. In addition to serving for five years as a mathematics professor at El Paso Community College, he was an adjunct mathematics faculty member and director of the Educational Talent Search Program at the University of Texas at El Paso (UTEP). Most notably, Frank was the first Mathematics Department chair for the first early college in El Paso, where he was selected as Teacher of the Year. Mission Early College High School, a collaboration between Socorro Independent School District, El Paso Community College, and the UTEP, went on to become a National Blue Ribbon School during his tenure.

Dr. Osvaldo Soto is DMPC's director and an Adjunct Professor at the Center for Research in Mathematics Education (CRMSE). Dr. Soto is interested in the development of secondary teachers' proof schemes and how teachers draw on their proof schemes to guide instruction. He brings nearly two decades of secondary teaching experience and 8 years of research-based professional development experience.

Dr. Fred Uy serves both as a Director in the Department of Educator Preparation and Public School Programs and Co-Director for the Center for the Advancement of Instruction in Quantitative Reasoning. Before joining the Office of the Chancellor, Dr. Uy was a Professor of Mathematics Education at Cal State LA and a K-12 mathematics teacher. In this position, he will be responsible in overseeing and increasing the capacity of the department to provide leadership and support to the educator preparation programs on campuses across the CSU. He has contributed to CSU initiatives in secondary school teacher mathematics preparation as a trainer for the EAP in Mathematics and as a leader in the CSU MTE-P. Dr. Uy also has served as a mathematics consultant for school districts and publishers and has conducted numerous professional development trainings in topics like mathematics pedagogy, teaching mathematics to ELs, assessments, Linked Learning, arts integration, and bilingual education.

Appendix C: Bridging the College Readiness Mathematics Gap (METRICS)

PRE-K-12

CURRICULUM				
The adopted curriculum is rigorous.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The adopted curriculum is reflective of standards.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

INSTRUCTION				
The instructors have a thorough knowledge of the subject area.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors use a variety of approaches to teaching.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors assess students in multiple ways.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors are sensitive to students' needs and backgrounds.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors	4	3	2	1

participate in ongoing professional learning.	(Highly Effective)	(Effective)	(Needs Improvement)	(Ineffective)
	Comments:			
The instructors revise and adjust their teaching as needed.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors connect to and model the real world.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

IN-SCHOOL COLLABORATION

The mathematics department collaborates with other departments within the school to ensure mathematics integration.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The mathematics department collaborates with other department to ensure validity of quantitative reasoning.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

COMMUNITY INVOLVEMENT

The school has established partnerships with industry, business and community sectors for externships, internships, mentoring, guest speakers, etc.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The school is an integral part of the community it serves.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

The school proactively involves the community in the learning process.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

FAMILY INVOLVEMENT				
Strong communication is established and encouraged between the school and the home.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The school communicates effectively with the home.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

ADDITIONAL TOPICS				
	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

Post-Secondary

CURRICULUM				
The curricular programs are rigorous and reflective of student-learning outcomes.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The curriculum is revised and adjusted as needed using a process of continuous improvement.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The lessons are connected to and model the real world.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The university requires default gateway level mathematics courses for each program or programs of study.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

INSTRUCTION				
The instructors have an extensive knowledge of the subject area.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors use a variety of approaches to teaching.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors assess students in multiple ways.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

The instructors are sensitive to students' needs and backgrounds.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors participate in ongoing professional learning.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The instructors connect to and model the real world.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

COLLABORATION				
The Mathematics Department works with partner disciplines to align mathematics pathways.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

STUDENT SUPPORT				
A First Year Experience (FYE) program is available to all students.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
Advising and academic counseling are extensively involved in student success.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
Tutoring and academic support (Help Center)	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)

are part of student success.	Comments:			
Self-advocacy is an integral part of the FYE.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
Resources for life skills, mental wellness, mentoring, peer counseling, etc. are provided to the students.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

COMMUNITY INVOLVEMENT				
The campus has established partnerships with industry, business and community sectors for externships, internships, mentoring, guest speakers, etc.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The campus is an integral part of the community it serves.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
The campus proactively seeks feedback from the community in the academic/educational processes.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

CAREER OPPORTUNITIES				
Students are applying their learned knowledge through internships, externships, work-study, etc.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

An effective communication system for career opportunities is in place.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
A system is established for alumni to mentor and support current students.	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

ADDITIONAL TOPICS				
	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			
	4 (Highly Effective)	3 (Effective)	2 (Needs Improvement)	1 (Ineffective)
	Comments:			

Appendix D: Annotated References

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Adelman, C. (2005). Executive Summary: The Toolbox Revisited: Paths to Degree Completion From High School Through College. *The Journal for Vocational Special Needs Education,*28(1), 23-30. Retrieved May 15, 2019, from https://files.eric.ed.gov/fulltext/EJ854364.pdf.

The Toolbox Revisited: Paths to Degree Completion From High School Through College

“The academic intensity of the student’s high school curriculum still counts more than anything else in precollegiate history in providing momentum toward completing a bachelor’s degree.

There is a quantitative theme to the curriculum story that illustrates how students cross the bridge onto and through the postsecondary landscape successfully. The highest level of mathematics reached in high school continues to be a key marker in precollegiate momentum, with the tipping point of momentum toward a bachelor’s degree now firmly above Algebra 2.”

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Blair, R., & Getz, A. (2011, June 09). A Brief History of the Quantitative Literacy Movement. Retrieved May 15, 2019, from
https://www.carnegiefoundation.org/blog/a-brief-history-of-the-quantitative-literacy-movement

A Brief History of the Quantitative Literacy Movement

“It has always been important for individuals to have the capacity to *do* arithmetic and algebra, however, in today’s global and technological society, doing calculations is not enough. An individual’s capacity to identify and understand quantitative situations, reason quantitatively, and communicate about the role mathematics plays in the world is essential. This quantitative literacy goes beyond basic computational skills. The quantitatively literate individual should be able engage in mathematics and solve quantitative problems from a wide array of authentic contexts and everyday life situations. These “habits of the mind” lead to making well-founded mathematical judgments that are useful in an individual’s current and future life as a constructive, concerned, and reflective citizen. Quantitative Literacy (QL) is more than just arithmetic skills and as fundamental as language literacy.”

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Boatman, A. (2012). Evaluating Institutional Efforts to Streamline Postsecondary Remediation: The Causal Effects of the Tennessee Developmental Course Redesign Initiative on Early Student Academic Success. A National Center for Postsecondary Research (NCPR) working paper. Retrieved on May 23, 2019 from
http://www.postsecondaryresearch.org/i/a/document/22651_BoatmanTNFINAL.pdf

Evaluating Institutional Efforts to Streamline Postsecondary Remediation: The Causal Effects of the Tennessee Developmental Course Redesign Initiative on Early Student Academic Success.

“Findings from this study indicate that, among students on the margins of the cutoff score, the effects of enrollment in developmental mathematics were positive and statistically significant on early student persistence as well as on the number of credits attempted but not completed in the first semester. Although these effects did not persist over time, as I find no statistically significant differences between groups after two years, students exposed to redesigned developmental mathematics courses had more positive outcomes than did their peers in non-redesign institutions during the same period and also when compared with students exposed to the previous version of traditional remediation within their institution in prior years. Students appear to have benefited from redesigned courses at two of the three institutions.”

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Bozick, R., Ingels, S., & Owings, J. (2008). Mathematics Coursetaking and Achievement at the End of High School: Evidence from the Education Longitudinal Study of 2002 (ELS:2002). Retrieved May 15, 2019, from https://files.eric.ed.gov/fulltext/ED499546.pdf

Mathematics Coursetaking and Achievement at the End of High School: Evidence from the Education Longitudinal Study of 2002.

“The findings show that the largest overall gains are made by students who take precalculus paired with another course during the last 2 years of high school. In terms of learning in specific content areas, the largest gains in intermediate skills such as simple operations and problem solving were made by those who followed the geometry–algebra II sequence. The largest gains in advanced skills such as derivations and making inferences from algebraic expressions were made by students who took precalculus paired with another course. The smallest gains were made by students who took one mathematics course or no mathematics courses during their last 2 years.”

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Burdman, P. (2018, November). The Mathematics of Opportunity. Retrieved May 23, 2019 from https://justequations.org/wp-content/uploads/je-report-r12-web.pdf

The Mathematics of Opportunity: Rethinking the Role of Educational Mathematics in Educational Equity.

“Just Equations’ report The Mathematics of Opportunity describes how traditional approaches to mathematics education can contribute to inequity and highlights emerging approaches to change that equation. The goal is to ensure that mathematics instruction is more equity-oriented and that mathematics requirements are more valid and aligned across educational systems.

Quantitative reasoning skills are an important underpinning for achievement in school, at work, and in life. But, perhaps because it plays such a primary role in fostering such skills, mathematics can be wielded in ways that arbitrarily close doors to educational advancement.”

✦

Byun, S., Irvin, M. J., & Bell, B. A. (2015, October 01). Advanced Math Course Taking: Effects on Math Achievement and College Enrollment. Retrieved May 15, 2019, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4620065/

Advanced Math Course Taking: Effects on Math Achievement and College Enrollment

"Using data from the Educational Longitudinal Study of 2002–2006 (ELS:02/06), this study investigated the effects of advanced math course taking on math achievement and college enrollment and how such effects varied by socioeconomic status (SES) and race/ethnicity. Results from propensity score matching and sensitivity analyses showed that advanced math course taking had positive effects on math achievement and college enrollment. Results also demonstrated that the effect of advanced math course taking on math achievement was greater for low SES students than for high SES students, but smaller for Black students than for White students. No interaction effects were found for college enrollment. Limitations, policy implications, and future research directions are discussed."

✦

Elrod, S. (2014, December 19). Quantitative Reasoning: The Next "Across the Curriculum" Movement. Retrieved May 15, 2019, from https://www.aacu.org/peerreview/2014/summer/elrod

Quantitative Reasoning: The Next "Across the Curriculum" Movement

"By one definition, quantitative reasoning (QR) is the application of basic mathematics skills, such as algebra, to the analysis and interpretation of real-world quantitative information in the context of a discipline or an interdisciplinary problem to draw conclusions that are relevant to students in their daily lives. It is not just mathematics. Carleton College, for example, views QR as "the habit of mind to consider the power and limitations of quantitative evidence in the evaluation, construction, and communication of arguments in public, professional, and personal life." The term numeracy is also used in conjunction with these skills."

✦

Finkelstein, N., Fong, A., Tiffany-Morales, J., Shields, P., & Huang, M. (2012). College Bound in Middle School & High School? How Math Course Sequences Matter. Retrieved May 15, 2019, from https://www.wested.org/online_pubs/resource1274.pdf

College Bound in Middle School & High School? How Math Course Sequences Matter

"Irrespective of students' math performance, taking four years of high-school math strengthens their postsecondary opportunities. For students seeking entrance to one of California's public university systems, a fourth year of math is strongly recommended. Yet our analysis shows that slightly more than 30 percent of students in the study sample did not take math during their senior year. For those who don't study math their senior year (as well as for others who may not move directly from high school to college), having to take a college placement test after at least a year away from math can be a major deterrent to placing into a college-level math course; and students who do not do well on their placement test are likely to end up in a developmental, or remediation, math course, which yields no college credit."

✦

Gao, N. (2016, July). Retrieved May 15, 2019, from https://www.ppic.org/publication/college-readiness-in-california-a-look-at-rigorous-high-school-course-taking/

College Readiness in California: A Look at Rigorous High School Course-Taking

"In this report we look at participation and performance in rigorous high school courses among California high school students, both overall and across demographic and racial/ethnic groups. While enrollment in rigorous courses has been increasing, particularly among students who are traditionally underrepresented in higher education, a large majority of California high school students are not taking the courses that can prepare them for college. Forty-three percent of high school graduates in 2015 completed the a–g requirement, and 27 percent of high school graduates in 2013 passed an advanced placement (AP) exam. Participation in advanced math, biology, chemistry, and physics courses is also low. In particular, only 30 percent of high school juniors and seniors enrolled in Algebra II and smaller shares enrolled in chemistry (28%) and physics (10%)."

✦

Jackson, J. & Lurlaender, M. (2013). College Readiness and College Completion at Broad Access Four-Year Institutions. *American Behavioral Scientist*, *58*(1), 947-971.

College Readiness and College Completion at Broad Access Four-Year Institutions

"Many students arrive at college unprepared to do college-level work, facing a host of college readiness assessments and developmental education coursework. In this article, the authors examine how a student's readiness to take college classes upon entry to the university is related to four longer-term postsecondary outcomes. They utilize a unique longitudinal dataset of the census of first-time freshmen at the nation's largest public 4-year state postsecondary system to describe differences by campus and across college majors. In addition they explore the use of one measure that the system does not currently use to determine readiness—high school grade point average—and its relationship with both the existing readiness measure and postsecondary outcomes. The results indicate that grade point average can be a useful predictor of college success above and beyond the readiness measure."

✦

Jenkins, D., & Bailey, T. (2017). Early Momentum Metrics: Why They Matter for College Improvement. New York, NY: Columbia University, Teachers College, Community College Research Center.

Early Momentum Metrics: Why They Matter for College Improvement

"In this brief, the authors propose three measures of "early momentum" that colleges can use to gauge whether institutional reforms are improving student outcomes:

> **1. Credit momentum**—defined as attempting at least 15 semester credits in the first term or at least 30 semester credits in the first academic year.
>
> **2. Gateway momentum**—defined as taking and passing pathway-appropriate college-level math and college-level English in the first academic year.
>
> **3. Program momentum**—defined as taking and passing at least nine semester credits in the student's field of study in the first academic year."

✦

Kim, S. (2018). Return to Algebra II: The Effect of Mandatory Math Coursework on Postsecondary Attainment. Retrieved August 15, 2019 from: https://www.bridgemi.com/sites/default/files/algebraii_nov.pdf

Return to Algebra II: The Effect of Mandatory Math Coursework on Postsecondary

"Using detailed transcript data from multiple cohorts in Michigan, this paper studies the long-run impacts of math course-taking on student outcomes and the impacts of mandatory Algebra II taking on college outcomes."

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Kim, S., Wallsworth, G., Xu, R, Schneider, B., Frank, K., Jacob, B., & Synarski, S. (2019). The Impact of the Michigan Merit Curriculum on High School Math Course-Taking. 41:2, 164-188. Retrieved August 15, 2019 from: https://www.bridgemi.com/sites/default/files/the_impact_of_the_michigan_merit_curriculum_on_high_school_math_course-taking.pdf

The Impact of the Michigan Merit Curriculum on High School Math Course-Taking

"Michigan Merit Curriculum (MMC) is a statewide college-preparatory policy that applies to the high school graduating class of 2011 and later. Using detailed Michigan high school transcript data, this article examines the effect of the MMC on various students' course-taking and achievement outcomes. The analysis suggests that (a) post-MMC cohorts took and passed approximately 0.2 additional years' of math courses, and students at low socioeconomic status (SES) schools drove nearly all of these effects; (b) post-policy students also completed higher-level courses, with the largest increase among the least prepared students; (c) we did not find strong evidence on students' ACT math scores; and (d) we found an increase in college enrollment rates for post-MMC cohorts, and the increase is mostly driven by well-prepared students."

✦

Logue, A., Watanabe-Rose, M., & Douglas, D. (2016). Should Students Assessed as Needing Remedial Mathematics Take College-Level Quantitative Courses Instead? A Randomized Controlled Trial. Educational Evaluation and Policy Analysis. 38:3, 578–598. Retrieved May 23, 2019 from: https://journals.sagepub.com/doi/pdf/10.3102/0162373716649056

Should Students Assessed as Needing Remedial Mathematics Take College-Level Quantitative Courses Instead?

“Many college students never take, or do not pass, required remedial mathematics courses theorized to increase college-level performance. Some colleges and states are therefore instituting policies allowing students to take college-level courses without first taking remedial courses. However, no experiments have compared the effectiveness of these approaches, and other data are mixed. We randomly assigned 907 students to (a) remedial elementary algebra, (b) that course with workshops, or (c) college-level statistics with workshops (corequisite remediation). Students assigned to statistics passed at a rate 16 percentage points higher than those assigned to algebra ($p < .001$), and subsequently accumulated more credits. A majority of enrolled statistics students passed. Policies allowing students to take college-level instead of remedial quantitative courses can increase student success.”

✦

Long, M., Conger, D., & Iatarola, P. (2012). Effects of High School Course-Taking on Secondary and Postsecondary Success 49:2, 285-322.

Effects of High School Course-Taking on Secondary and Postsecondary Success

“Using panel data from a census of public school students in the state of Florida, the authors examine the associations between students' high school course-taking in various subjects and their 10th-grade test scores, high school graduation, entry into postsecondary institutions, and postsecondary performance. The authors use propensity score matching (based on 8th-grade test scores, other student characteristics, and school effects) within groups of students matched on the composition of the students' course-taking in other subjects to estimate the differences in outcomes for students who take rigorous courses in a variety of subjects. The authors find substantial significant differences in outcomes for those who take rigorous courses, and these estimated effects are often larger for disadvantaged youth and students attending disadvantaged schools.”

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Long, M., Iatarola, P., & Conger, D. (2009). Explaining Gaps in Readiness for College-Level Math: The Role of High School Courses. Education Finance and Policy 2009 4:1, 1-33.

Explaining Gaps in Readiness for College-Level Math: The Role of High School Courses

“Despite increased requirements for high school graduation, almost one-third of the nation's college freshmen are unprepared for college-level math. The need for remediation is particularly high among students who are low income, Hispanic, and black. Female students are also less likely than males to be ready for college-level math. This article estimates how much of these gaps are determined by the courses that students take while in high school. Using data on students in Florida public postsecondary institutions, we find that differences among college-going students in the highest math course taken explain 28–35 percent of black, Hispanic, and poverty gaps in readiness and over three-quarters of the Asian advantage. Courses fail to explain gender gaps in readiness. Low-income, black, and Asian students also receive lower returns to math courses, suggesting differential educational quality. This analysis is valuable to policy makers and educators seeking to reduce disparities in college readiness."

✦

McNair, T.B., (2018) Become a Student-Ready Institution. Leadership Exchange. 16:1, 21-25

[Become a Student-Ready Institution]

"Over the last 18 months, my coauthors and I have engaged in conversations with educators about what it means to become a student-ready institution, stemming from our 2016 publication of Becoming a Student-Ready College: A New Culture of Leadership for Student Success. The book was written in response to national conversations and efforts to advance student success in postsecondary education. The term "student ready" comes from a belief that if significant progress is to be made in the student success agenda, there must be a paradigm shift in how educators design and lead student success efforts. Instead of focusing solely on students being college ready and on students' perceived deficits, educators must focus on what they can do to create educational environments that meet students where they are and eliminate barriers that hinder their success."

✦

One Year Out: Findings From A National Survey Among Members Of The High School Graduating Class Of 2010(Rep.). (2011). Washington, DC: Hart Research Associates. Doi: http://secure-media.collegeboard.org/homeOrg/content/pdf/One_Year_Out_key_findings report_final.pdf

[One Year Out: Findings From A National Survey Among Members Of The High School Graduating Class Of 2010]

"Four in nine members of the class of 2010 say that based on what they know now they wish they had taken different courses in high school, with the largest proportion of these graduates saying they wish they had taken more math courses or more difficult math courses. 44% say that they wish they had taken different courses in high school. Among this group, 40% would have taken more or higher level math courses, 37% would have taken courses that would have trained them for a specific job, and 33% would have taken more or higher level science courses. Regrets about course selection are higher than average among students who went on to college but felt less well prepared than others at their college, students who considered dropping out or did drop out of college, and students who were required to take non-credit remedial courses once they got to college."

✦

Rigor at Risk: Reaffirming Quality in the High School Core Curriculum (Rep.). (2007). Iowa City, IA: ACT. Doi: https://www.act.org/content/dam/act/unsecured/documents/rigor_report.pdf

Rigor At Risk: Reaffirming Quality in the High School Core Curriculum

“Of those students who take a core mathematics curriculum, only 16 percent are ready for a credit bearing first-year College Algebra course (see Figure 4). It is not until students take one full year of additional mathematics courses beyond the core that we see more than half (62 percent) of ACT-tested students ready for college-level work in mathematics.”

✦

Rose, H., & Betts, J. (2001). Math Matters: The Links Between High School Curriculum, College Graduation, and Earnings. Retrieved May 15, 2019, from https://www.ppic.org/content/pubs/report/R_701JBR.pdf

Math Matters: The Links Between High School Curriculum, College Graduation, and Earnings

“Considerable evidence suggests that differences in years of schooling explain a large portion of the income gap in the nation and in California. Many have inferred that the growing income gap can be narrowed by better educating people at the lower end of the income distribution, especially minority students.

It stands to reason that it is not just years of education, but the type of education—the courses taken during school—that affects the earnings of high school students years later. There is some limited evidence that students who take more math in high school are more likely to pursue postsecondary education and to have higher earnings in the future. However, it has not been established how strong these relationships are, for what groups they exist, and what else might explain the apparent effect of curriculum on postsecondary education and future earnings.

Despite the belief that an enhanced curriculum is one way to improve students’ college attendance rates and earnings, the few studies that do include curriculum in estimates of these long-run student outcomes generally find minimal effects. The notion that the actual courses that students take in high school do not matter raises serious questions about the effectiveness of the American public school system’s curriculum. Therefore, it is essential to investigate further.”

✦

Scott-Clayton, J., & Stacey, G. W. (2015). Improving the Accuracy of Remedial Placement. New York, NY: Columbia University, Teachers College, Community College Research Center.

Improving the Accuracy of Remedial Placement

“This practitioner packet summarizes CCRC’s research on remedial placement at community colleges, and considers how using students’ high school transcript information in the assignment process could improve placement accuracy. Part one, *Improving the Accuracy of Remedial Placement*, provides an overview of the research, including evidence on the accuracy of typical practices, alternative methods of remedial screening, and the predicted impacts on student subgroups of using high school transcript information (instead of or alongside standardized tests) for placement. Part two, *Improving Assessment and Placement at Your College: A Tool for Institutional Researchers*, presents a framework for understanding and improving assignment to developmental education."

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The Value of the Fourth Year of Mathematics (Rep.). (2013). Washington, DC: Achieve. doi:https://www.achieve.org/publications/value-fourth-year-mathematics

The Value of the Fourth Year of Mathematics

"Too many students and educators view the senior year and graduation from high school as an end point, rather than one vital step along the education pipeline. Students who engage in a fourth year of math tap into and build upon their advanced analytic skills and are more likely to have better success in postsecondary course work, as they have maintained their momentum and continued to practice mathematics throughout their high school experience."

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White, B. The Myth of the College-Ready Student. (2016). Inside Higher Ed. Rtereived May 23, 2019 from https://www.insidehighered.com/views/2016/03/21/instead-focusing-college-ready-students-institutions-should-become-more-student

The Myth of the College Ready Student

"Look to your left and look to your right. The odds are one of you is not going to graduate."

Many of us who attended college in years past will recall receiving some such an admonition from a professor or adviser. The message was simple: our job is to give you an opportunity; your job is to take advantage of it. If you don't, oh, well.

It was a straightforward arrangement that for decades buffered higher education from a harsh reality that only recently has come under public scrutiny: more than one-third of students who begin their degree never finish. Those in higher education didn't think too much about it because we did not consider ourselves responsible.