Objectives and Broader Educational Context for Iowa's Planned Work on the Mathematics Transition from High School through College

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by

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Goal and Objectives

Goal: An effective mathematics transition from high school through college for *all* students

Objective 1: Effective High School Pathways

- Aligned with student needs, backgrounds, college and career options
- More than the intensive-algebra-calculus pathway
- Flexible options after Algebra 1
- Four years of mathematics, including in the senior year
- Pathways with flexibility and mathematical integrity, not tracking

Objective 2: Effective Transition from High School to College

- Multiple-measures placement strategies for the first college math course
- Appropriate college courses or college credit in high school (concurrent enrollment, AP, IB, PSEO, etc.)
- Effective transition courses in high school for college readiness
- Clearly articulated and communicated mathematics expectations from colleges and universities

Objective 3: Effective Initial College Math Courses

- Provide effective pathways leading into different programs of study
- Reduce the barrier of no-credit remedial mathematics courses
- Streamline prerequisites, especially regarding the issue of Algebra 2 (Intermediate Algebra) as an entrance requirement or prerequisite for college-credit math courses
- Consider a co-requisite model for STEM courses
- Reexamine and consider redesign of entry-level mathematics courses, including: intervention courses, remedial algebra, college algebra, pre-calculus, quantitative literacy, statistical literacy, mathematical literacy, developmental mathematics, mathematics for liberal arts, and courses that provide a broader view of mathematics for all students

Broader Educational Context

The goal and objectives of the planned work exist in a broader educational context. Discussion of various dimensions of this broader context follows—particularly as pertains to pedagogy, equity, teacher professional learning, and a contemporary view of mathematics. After each dimension is briefly presented, questions for consideration are proposed. These questions are intended to help ensure that we take into account surrounding issues of education and mathematics as we think about practical transition strategies and effective course pathways that help students and teachers alike achieve an effective mathematics transition from high school through college.

Earlier transitions

While the purpose of the summit is primarily upon transitions from high school to college, within college, and from college to careers, we must acknowledge that students arrive at these critical junctures with a history and mindset shaped by over a decade of mathematics learning. From students' perspectives, they have already transitioned from elementary to middle school, and then middle school to high school. If we are dissatisfied at times with the outcomes of these prior experiences and transitions, we must be careful not to replicate negative aspects of the K-12 educational system or surely, we will have similar outcomes and perpetuate challenges that have been well-documented by others over time. By considering the prior experiences of students, we can then turn a critical lens upon our own processes, practices, and assumptions in order to implement strategies that disrupt and challenge the status quo to achieve greater success.

Question for consideration:

- *As we think about an affective mathematics transition from high school through college for all students, how can we learn from and build upon student's earlier educational transitions?*

Disparate opportunities to learn

Student achievement is influenced through many factors; however, the most important factor is the "opportunity to learn" (OTL) (Wang, 1998; Elmore & Fuhrman, 1995). Essentially, the more time students spend on high-level mathematics content, the more likely they are to achieve at higher levels. Unfortunately, students of color, those from low-income families, Emerging Bilinguals, and students with mild to moderate disabilities have less access to grade-appropriate assignments, quality instruction, deep engagement, and high expectations from teachers (TNTP, 2018). In a recent report, these student subgroups described their secondary school experiences as being consistently below grade level and engaging less than half of the time.

Within the state of Iowa, school districts vary dramatically in terms of resources available, teacher quality in terms of licensure, experience, and access to professional development, and the associated learning experiences available to students. While effecting these factors is difficult, there is a growing body of evidence that *active learning* can improve student learning outcomes, student engagement, and student attitudes in STEM courses ranging from middle school through college and provide a needed intervention regardless of the local context or school environment (e.g., Star & Verschaffel, 2017; Jiang & McComas, 2015). In addition, teacher-centric instructional methods that are passive in nature have been correlated with lower student achievement levels and greater disparities in achievement for minority, low-income, and first-generation students. A consensus of research has demonstrated both better outcomes in terms of students' learning as well as dispositions to learning and self-esteem in relation to active learning approaches across STEM disciplines (CBMS, 2016; Freeman et al., 2014; Prince, 2004). However, these approaches are notably lacking in secondary and tertiary STEM classrooms regardless of teachers' experience levels (Banilower et al., 2006; Capps & Crawford, 2013).

Questions for consideration:

- *In what ways do high school math pathways replicate these educational disparities?*
- *How could they be revised to result in more equitable educational outcomes?*

Fixed mindset versus growth mindset

While many STEM initiatives have been launched at the state level and within STEM hubs to foster enthusiasm for STEM careers and the associated coursework, educational policies have remained in place that are punitive in nature and diminish students' enthusiasm and motivation to pursue mathematics coursework. Specifically, the statewide use of tracking and frequent reporting of individual test scores send a negative and fixed mindset message to many students that remains a consistent stream of feedback throughout their secondary schooling. Prior to entering high school and sometimes as early as fourth grade, most students in Iowa are sorted into either an accelerated track for mathematics, a general education mathematics track, or occasionally a remedial track. Changing between tracks is extremely difficult in most cases, and limits many students' access to calculus courses in high school or other advanced coursework. Students who perhaps previously enjoyed and favored mathematics but fail to place into accelerated mathematics tracks, receive a strong message that what they once viewed as a strength or a preference does not align with the school system's evaluation. These external judgements and verdicts are contrary to research and beliefs related to growth mindsets, which advocate that all students have the capacity and ability to achieve at high levels and contribute in multiple ways to the classroom learning environment. In addition, the messaging sets the stage for students to disengage, feel defeated, and seek alternatives to mathematics-related fields. Interestingly, high performing students are the ones most negatively influenced by fixed messages they receive when moving into tracked mathematics classes (Romero, 2013), perhaps in spite of their parents' perceptions and wishes (Loveless, 2009).

The negative effects of tracking and frequent reporting of test scores have been shown to create long-lasting and harmful consequences for students by sending a message that mathematics ability is fixed in nature (Boaler, 2016). In response, some school across the United States are attempting to remove tracking in mathematics (See https://www.edweek.org/ew/articles/2018/06/13/a-bold-effort-to-de-track-algebra-shows.html?r=6585978) , and others are radically placing all students into at least one advanced course in grade 9 (See https://www.denverpost.com/2020/01/02/george-washington-high-integration-honors-classes/).

Questions for consideration:

- *In what ways are we replicating the negative impacts of tracking through college placement processes and associated courses?*
- *How can these unintended consequences and negative impacts be addressed?*

Teachers' roles and awareness of tracking and fixed mindsets

Currently, most secondary STEM teachers do not fully understand their critical role in driving social change that brings about more equitable learning outcomes including the reduction of tracking. For example, 70% of secondary mathematics teachers strongly agree or agree that students learn best in mathematics classes with students of similar ability (Banilower et al., 2018). This stance perpetuates the tracking of students and ultimately inequitable learning outcomes by sorting students of different backgrounds into remarkably disparate learning experiences. Encouragingly, El Nagdi, Leammukda, and Roehrig (2018) found that STEM middle school teachers within STEM magnet schools were fully committed to bridging achievement and cultural gaps between students. However, at the secondary level, Garibay (2015) found that majoring in a STEM discipline had a notable negative association with social agency outcomes, thus highlighting the probable challenges for implementing equitable instruction. Such findings are not surprising given that Western tradition has dominant views on knowing and doing science and mathematics (Boaler & Sengupta-Irving, 2006; Phillip, 2007). It would seem that teachers and policy makers do not truly believe that all students have the capacity and ability to learn mathematics and science at high levels. The educational system reflects these beliefs by erecting barriers to learning through tracking and early messaging that STEM fields are relegated to specific populations of students.

Questions for consideration:

- *In what ways are these factors shared at the college level? Do college professors believe that all students can learn?*
- *If so, do these beliefs translate into tangible actions in terms of course placement, the learning environment, and culturally responsive teaching?*

Disconnect between testing and future achievement

Historically, K-12 mathematics teachers created their own assessments or utilized assessments from textbooks to determine how much students learned. In this way, curriculum and assessment were tightly linked. With the adoption of the Common Core State Standards (CCSS-M) (NGA & CCSSO, 2010), grade-level learning objectives are specified regardless of the curriculum employed by each school or district. Many schools have adopted assessments such as MAP, generated by a non-profit organization NWEA (See https://www.nwea.org/map-growth/), to assess learning multiple times throughout the academic year. MAP utilizes item-response theory to gauge students' growth in learning between testing intervals and highlights areas that might require further instruction. These assessments do not replace pre- and post-assessments that teachers may administer at the beginning and completion of a unit or the mandatory annual programmatic assessment, e.g. Iowa Assessments. In Finland, one of the highest-scoring countries in the world, students do not take any tests in school. Additionally, researchers have found that over-testing and reporting of grades reduces student achievement as students begin to see themselves as test scores and grades rather that active participants in the learning process (Elwar & Corno, 1985; McDermott, 1993). In contrast, rich feedback provided by the instructor allows the students to take ownership of their own learning and make progress, which leads to achievement, persistence, engagement, and positive dispositions (Boaler, 2016).

Over the last decade, dissatisfaction with the heavy emphasis on test scores and related myopic assessment items has been brewing in both academia and industry. Google stated that they are no longer interested in students' test scores, as they in no way predict success in the workplace (Bryant, 2013). Similarly, over one-third of colleges and universities across the United States no longer require ACT or SAT test scores as part of the admissions process for related reasons. Further, researchers have clearly shown that the knowledge needed to successfully complete a multiple-choice mathematics test is unrelated to the analytical thinking needed for most STEM courses and creates a false sense of who is or is not proficient in math (Boaler, 2016). When the CCSS-M were new in nature, Iowa, along with other states, considered adopting a new assessment created to both align with the standards and addressed concerns about the link between test results and future outcomes. The two main tests considered were: 1) the Smarter Balanced Assessment (SBAC) (See http://www.smarterbalanced.org), and 2) the Partnership for Assessment of Readiness for College and Careers assessment (PARCC) (See http://wwwparcconline.org).

After several years of debate, Iowa chose to continue with Iowa Assessments primarily due to budgetary reasons. While disappointing to many educators, the two newer assessments created by SBAC and PARCC have provided only moderate explanatory information thus far to teachers in other states, as efforts to incorporate performance assessments items has proven to be complex, costly, and prone to under-reporting what student know and can do (Roach et al. 2010). These performance test items were created so that assessments could gauge students' abilities to communicate, reason, and problem solve. Due to the inability to deliver performance tasks in a way that accurately represented what students know and can do coupled with budget issues around test administration and scoring, the new assessments administered each year largely resemble those utilized prior to the adoption of the CCSS-M and consist mostly of routine skill items. For the few items that do require an increased level of thinking or the ability to explain, students overwhelmingly perform poorly, and thus teacher are not provided with new information regarding where students may need remediation (Sriraman & Haavold, 2017).

It is important to note that the United States is the only country that has accountability testing in the sense that student test scores are utilized to gauge the effectiveness of mathematics teaching by a teacher, a school's mathematics program, a district, etc. In addition, tests are utilized to assess students and either allow or gate them from progressing further. These high-stakes situations create an increased need for reliability and validity of test scores, which again limits the types of questions, content, and scenarios that are presented to students. These limiting factors influence the curriculum being taught ultimately, as teachers tend to gear their instruction to what will be assessed and measured. In this way, the full breadth of the Common Core State Standards and Mathematical Practices has not been realized in the K-12 mathematics curriculum.

Questions for consideration:

- *How do placement tests potentially under-represent what students know and can do and privilege "good test takers" versus those who can reason, communicate, and make sense of mathematics?*
- *By focusing on test results generally, how are we narrowing the mathematics being taught and learned in ways that don't prepare students for STEM fields, modern careers, and citizenship?*

Developing and supporting our mathematics teachers

Three particular issues in developing and supporting mathematics teachers are highlighted here: dealing with COVID-19, culturally-responsive teaching, and teacher tracking.

Amid the great uncertainty and challenges of the COVID-19 pandemic we must support our teachers in every way we can: mathematically, professionally, and personally. First of all, we acknowledge the increased level of stress and a new hierarchy of needs where mathematics pathways and transitions, while still eminently important and the focus of our planned summit, are not at the top of the list. We will work together and collectively figure out how to create safe engaging learning environments and how to maintain our implementation of best practices such as active learning, mathematical modeling, and rich mathematical discourse while dealing with new modes of socially-distanced and online education.

There are of course a myriad of other professional learning and support issues that are important, including some that are relatively new. For example, the term, *teacher tracking*, has been coined by the National Council of Teachers of Mathematics (2018) in order to highlight educational disparities that result from assigning the least experienced teachers to the most demanding courses. Teacher tracking is depicted as placing teachers with the most experience, or those perceived as the most effective, in upper-level math courses and the teachers with the least experience in entry-level courses or with populations of students who are underserved. Setting student outcomes aside, teacher tracking increases isolation and burnout for early career teachers and reduces the professional collaboration necessary to improve teaching (NCTM, 2018). These practices are often replicated within colleges and universities and are part of a systemic prioritization scheme that creates additional barriers for struggling students and sends a clear message to the teachers of their perceived value. Similar to student tracking, teacher tracking is part of a complex system of policies, traditions, and societal expectations that is passed down year after year and rarely challenged.

In addition to tracking once hired, disparities between districts in teacher quality emerge during the hiring process. The most qualified new mathematics teachers, in terms of in-discipline coursework completed, are often recruited aggressively upon graduation. These teachers tend to select positions in suburbs versus high need schools based upon teaching conditions and the availability of resources (Sutcher, Darling-Hammond & Carver-Thomas, 2016). Other national trends document ongoing teacher shortages in mathematics and sciences and predict that the shortages will grow in coming years. In the 2015-2016 academic year, 40 states reported teacher shortages in mathematics and sciences with low-income and minority schools experiencing teacher shortages at about four times the rate of high-income schools (USDOE, 2019). Given these statistics, it is not surprising that we have observed similar trends in the state of Iowa with chronic shortages of mathematics teachers in rural and metro districts (IDOE, 2019).

Once in place, many beginning high school and college-level mathematics teachers must not only strive to implement best practices, such as active learning pedagogies, and but they must also incorporate culturally responsive approaches in order to reach all the students within their classrooms. At times, teachers may inadvertently contribute to inequitable instruction by employing culturally-based analogies and examples that only some students understand (Irish & Kang, 2018). Alternatively, teachers might utilize active learning approaches to explore phenomena or authentic tasks in order to build common experiences and knowledge (Wagner, 2012). However, researchers have also found that teachers need specialized content knowledge to utilize these pedagogies effectively, and that this knowledge grows over time and with teaching experiences. For example, teachers must know how to represent ideas in different ways, how to interpret students' ideas, and how to respond to students productively (Ball & Forzani, 2010; Gess-Newsome, 1999). Given the extreme challenges associated with being a new teacher of mathematics, one must question practices that systematically place the least experienced teachers in the most demanding and complex situations.

Questions for consideration:

- *What changes are needed in pre-service and in-service teacher education to meet the challenges of COVID-19, teacher tracking, and culturally-responsive teaching?*
- *How can we disrupt systemic policies that harm new mathematics teachers and their students?*
- *What changes would take place in our high schools, colleges, and universities, if we put students and teachers first in terms of teaching and learning of mathematics?*

Broader view of general education mathematics in the 21st century

What mathematics is most relevant, and accessible, for *all* college students to help them become engaged, literate citizens in the modern world? Inspired by the seminal book *On The Shoulders of Giants: New Approaches to Numeracy* (Steen, 1990), perhaps we should design a robust college mathematics course for all students based on the "developmental power of deep mathematical ideas" (p. 5). In that book, the ideas chosen are dimension (especially in space and geometry), quantity (including ideas of number and algebra), uncertainty ("intended to suggest two related topics: data and chance," p. 95), shape (but "Euclid is not sufficient for geometry," p.140), and change (including continuous and discrete change). These themes are also found in the new PISA 2021 Mathematics Framework (OECD, 2018). In addition, reports such as *The Mathematical Sciences in 2025* (NRC, 2013), highlight the "rise of discrete mathematics" (p. 72) and "computation and big data" as new drivers of mathematics (p. 77).

Borrowing from all these recommendations, we could design a course that is truly "developmental" around the mathematical themes shown in the table below. Importantly, these themes are not only deep ideas of mathematics but also highly relevant for developing educated citizens in our contemporary technological, networked, data-intensive, democratic society.

Theme	**Some relevant areas of mathematics**	**Possible topics for a robust and relevant general education transition mathematics course**
Quantity	Number and operations, number theory, combinatorics	Proportional reasoning, counting methods, Venn diagrams to organize quantitative information
Shape	Geometry	Form and function, transformations and symmetry
Data and Chance	Data Science, Statistics and Probability	Designing investigations; data collection, exploration, visualization, and modeling; inference and decision making; error-likelihood analysis; security and ethics

Change	Algebra, calculus, discrete dynamical systems	Constant rate of change (linear), constant percent rate of change (exponential), including recursive representations; simple and compound interest, patterns of association in bivariate data
Networks	Graph theory	Vertex-edge graph models (e.g., for prerequisite and conflict relationships, for optimum routes, and for social, communication, and transportation networks)
Computing and the Internet	Informatics	Internet privacy/security (e.g., public-key cryptography), algorithmic problem solving
Fairness	Mathematics of voting, fair division, game theory	Ranked-choice voting, weighted voting, fair division and apportionment, ethical algorithms

Questions for consideration:

- *Are we teaching the most appropriate mathematics to best prepare all students for lives and careers in the modern world?*
- *Have we disadvantaged non-STEM students by not giving them the opportunity to learn topics from statistics, probability, and discrete mathematics?*
- *Have we disadvantaged STEM students by not giving them the opportunity to gain broader skills and perspectives in mathematical topics outlined above?*

Final question for consideration:

As we think about practical transition strategies and effective course pathways that help students and teachers alike achieve an effective mathematics transition from high school through college, how do we ensure that we also take into account the broader issues of society, education, and mathematics?

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