Design Requirements for Next Generation Gateway Mathematics Courseware

A Possible Model for Scalable Implementation

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Introduction

College-level mathematics is one of the most common–and formidable–barriers to completion of postsecondary degree programs, particularly for first-generation, lower-income students. In light of this, a consensus has emerged among top mathematicians and higher education leaders that the discipline needs to reengineer the way that introductory mathematics is taught. The expectation is that courses developed according to current standards in instructional design that also provide developmental support in foundational concepts and skills in a more nuanced way and better align introductory mathematics with students' major and career trajectories will result in successful outcomes for more students. At the same time, advances in machine learning technology have led to digital courseware that is better able to tailor content and provide targeted support to address students' individual needs in a more efficient way. There is significant potential for such adaptive courseware to help effectuate the shifts in curriculum and pedagogy envisioned by the math reformers, and to help scale those shifts cost-effectively.[1]

This document lays out a set of software specifications for a courseware product that a college or university might use to teach gateway math courses in a hybrid format, aligned to the Math Pathways Model developed by the Charles A. Dana Center at the University of Texas, Austin and the Carnegie Foundation for the Advancement of Teaching. Under the Math Pathways Model, all students—including those with developmental needs—enter a credit-bearing mathematics course whose curriculum is aligned to their major field of study and which prioritizes active learning and relevant application and incorporates tailored remedial and other student support on an as-needed basis. To facilitate cost-effective scaling of the model across instructors and institutions, the courseware and its wrap-around support system must not require significant new expenses for institutions to adopt and use effectively.

These proposed specifications are based on the lessons of the Adaptive Learning in Statistics (ALiS) project in developing and testing a next generation approach to the teaching of introductory statistics at two-year and four-year public institutions in Maryland.[2] While the project did not produce conclusive evidence of the effectiveness of

[1] See the annotated resources list at the bottom of this document, particularly the sections on Guided Pathways, New Math Pathways, and Adaptive Learning Technology.

[2] The key results and lessons learned from the ALiS project are described more fully in the Ithaka S+R report, Jenna Joo and Richard R. Spies, "Aligning Many Campuses and Instructors around a Common Adaptive Learning Courseware in Introductory Statistics: Lessons from a Multi-Year Pilot in Maryland," Ithaka S+R, 7 November 2019, https://sr.ithaka.org/publications/adaptive-learning-courseware-introductory-statistics.

the intervention in terms of improved student success, some of the tacit knowledge gained through aligning many campuses and instructors around the development and implementation of the common courseware and resources provide a good basis for knowing the important elements of that process, in particular, in the design of the courseware.

Recognizing that there may be a variety of ways to tackle the goals of effectiveness and scalability, one possible model for courseware design and delivery is offered here. While the document was prepared with courseware providers and developers in mind as the primary target audience, it may be also valuable for faculty and other institutional leaders who are thinking about or are already experimenting with various innovative course design and delivery strategies to improve student outcomes and increase instructional efficiency and effectiveness. Finally, since the document is a culmination of the collective learnings gained from the literature and the project, the pronoun "we" will be used throughout to reflect the collaborative nature of this ongoing endeavor.

Assumptions and Caveats

As a key component of the ALiS project, this document presents a conceptual model for adaptive learning courseware that can be collaboratively designed, maintained, and taught at multiple higher education institutions to serve student populations with varying levels of learning needs in math. The document was developed based on two overarching hypotheses that are aligned with the larger project goals. These hypotheses are that:

- Courseware delivered on an adaptive learning platform coupled with complementary active learning pedagogy in classrooms can significantly improve student outcomes, especially for those who would otherwise struggle with gateway math courses; and

- Such a course, with agreed-upon learning outcomes and delivery strategies, supported by strong institutional leadership, can be taken to scale without increasing costs, which would help improve student outcomes on a system- or state-wide basis and facilitate transfer of credit between institutions.

The work of the Dana Center and other collaborative initiatives in higher education as well as our experience with the ALiS project to date attest to the fact that any kind of pedagogical change in higher education takes time and persistence; in fact, it requires a significant shift in mindset at the individual and collective levels and an extraordinary amount of people work to make it successful and sustainable. The key assumption that lies behind the ALiS project is that the potential for improvement in student outcomes is

significant enough to warrant such an effort in change management, both in terms of success rates in gateway math courses and in terms of opening doors to those students to further educational and career opportunities that would be foreclosed without successful completion of such courses.[3] No matter how "good" or "complete" the courseware and its support package may be, the success of their implementation still depends heavily on a core instructional team that is committed to the particular mode of teaching and motivated to engage others in it. Likewise, institutional and departmental commitment that cultivates both faculty and student engagement and buy-in with the new approach is equally as important and cannot be overlooked. We urge readers to keep these assumptions and caveats in mind while engaging with the ideas presented in this document.

Intended Audience

This document is intended to serve as a guide for courseware providers and developers who wish to provide *a one-stop-shopping package solution* for a large number of institutions within a system, state, or consortium. Those institutions must be prepared to adopt a common syllabus along with agreed-upon courseware while also using a common set of instructor training materials and course delivery strategies.

Since the envisioned product strives to be a truly one-stop-shopping solution, all courseware features presented in this document are considered important and, therefore, of high priority. While it is recognized that very few platforms will be able to address all of these high priorities equally well, we believe that the features and functional requirements outlined here are critical to developing robust courseware that has the potential to be both effective and scalable. How institutions select among competing products with different strengths and weaknesses among these features will depend on their particular needs and circumstances.[4]

Contents Overview

The document begins with the product overview, specifically its scope, perspective, features, organization, possible user classes and characteristics as well as a possible organizational model. The following section will delve deeper into each product feature and describe its functional requirements. The document concludes with a summary along with a set of recommendations for courseware providers. A list of annotated resources, featuring key theoretical and practical resources (articles, videos, guides, etc.)

[3] See Huang's 2018 impact report, resource #16, which covers six year results from Carnegie Math Pathways work.
[4] The Courseware-in-Context, or CWiC, Framework may be a useful resource when choosing a product; see resource #29.

that have informed the development of this document, is included at the end of the document.

Product Overview

Product Scope

The product specifications were developed without a specific platform in mind but assuming the availability of next generation courseware features and capacities outlined in the CWiC Framework (see Annotated Resource List for more information). The courseware should be self-contained but meet the highest interoperability standards. It may be a new product or a follow-on member of an existing product family.

The courseware should be a self-contained gateway mathematics course that incorporates all curricular and co-curricular components of the Pathways Model. These components should include learning outcomes, content, scope and sequence aligned to national and state standards for awarding college credit in the relevant subject; adaptive features that personalize the students' learning pathways, including assessments of foundational mathematics skills and concepts needed for the course and associated instruction; exercises and assessments that prioritize application of concepts in situations relevant to the students' major and a dashboard where instructors can get real-time insight into student activity and performance in the courseware.

The courseware should permit a limited amount of enterprise-level customization; in particular, it should include a set of internally coherent default settings that adjust the learning outcomes, content, scope, and sequence to align to the gateway mathematics requirements of common majors. The courseware should also include integrated instructor training in the use of the courseware, as well as in the concepts and pedagogical practices required for effective implementation of the Pathways Model. Finally, the courseware should meet the highest standards for seamless interoperability with other common platforms used in higher education, especially learning management systems.

In the case of the ALiS course, an important goal was to ensure that the course would be taught in a consistent way across a range of institutions, including both two-year and four-year public institutions. This meant that the courseware had to be accompanied by extensive training and other resources for the instructors in those diverse institutions, including many who were teaching this kind of course for the first time and, as is the case with many adjunct faculty, had little time to prepare or consult with colleagues about how teaching this kind of a course is different from the teaching that most of them have

done in the past. The more the courseware package can provide a road map for the instructor to follow, including guidance about how to promote active learning and use a flipped classroom approach, the more effective it is likely to be for both students and instructors. Table 1 describes the major features of the courseware and their potential impact on student learning.

Table 1. Description of Features and their Potential Impact on Student Learning

Product Features	Description	Potential Impact on Student Learning
Pre-programmed Course Content Blocks	This feature includes off-the-shelf course content with embedded activities and assessments that are modularized to make it easy for designated users to "assemble" a course that is consistent with appropriate standards and address unique curricular needs of different programs. It will reduce the time and resources often required to build brand new courses and allow users to easily customize a course while preserving its quality and relevance. It is assumed that leaders at the participating institutions are actively engaged in co-maintaining the course content on an ongoing basis.	This feature would allow students in different program areas to learn gateway math in ways that are relevant and meaningful for their unique academic interests and career goals. Moreover, since the course content are co-maintained by leaders at multiple institutions, students would have access to high quality content that are continually updated to meet their learning needs in today's rapidly evolving world.
Rich Content Library and Course Authoring Tool	This feature provides a rich content library through which instructors can access a variety of standalone problems, activities, and/or assessments (non-adaptive) that can be downloaded for use in a face-to-face classroom or inserted into the courseware through the course authoring tool. One of the things that the ALiS team learned from piloting an adaptive introductory statistics courseware in Maryland institutions in a blended format (e.g., flipped classroom approach) is that many instructors wanted additional exercises and problem sets that can be used in classrooms to promote active learning.	This feature would deepen students' learning experience by providing additional instructional resources that instructors can use in classrooms to connect what students learn in the courseware with what they do in the classroom. The activities and exercises would allow instructors to give on-the-spot and targeted feedback to students in classroom to maximize their learning gains.
On-Demand and Just-in-Time Training Materials	This feature provides embedded course-specific training materials for instructors and students to allow them to take full advantage of the courseware and its adaptive features. The feature is intended to readily onboard instructors and students to engage with teaching and learning in new ways. Particularly for part-time or adjunct instructors, who are often hired close to the start of the semester, this feature	This feature would allow students to quickly learn the underlying design principles of the courseware and how each feature is intended to promote their learning. Students would also receive high quality, targeted support from instructors who receive appropriate level of

	would allow them to quickly prepare to teach the course. For those who have already had experience the course, the feature allows them to selectively access the materials in an on-demand basis.	training on both pedagogy and technology.
Pre-Assessment and Personalized Remediation for Students	This feature embeds course-specific pre-assessments in foundational math concepts and skills at appropriate points in the curriculum along with personalized remediation designed to address students' learning needs as they engage with the course content. This feature is designed to help students make timely progress completion of the course by embedding robust support within the courseware.	This feature would allow students to continually assess their learning and get appropriate and timely remediation while enrolled in their courses. The assessment data are collected and made available to individual students and instructor so they can continually monitor and improve their learning.
Embedded and Adaptive Formative Exercises for Students	This feature includes embedded and adaptive formative exercises in the courseware that provides ample opportunities for students to practice and test their growing knowledge before getting to the graded assignments. The exercises are designed to help students develop quantitative reasoning skills that will help further their education and ultimately advance their career trajectory.	This feature would allow students to practice math concepts in a variety of contexts through activities involving real-life examples and data.
Real-Time Feedback and Automated Tutoring for Students	This feature provides real-time feedback and automated tutoring to students in the form of a simple hint, video, graph or other additional resources based on how students perform and engage with the course content. This feature is designed to steer students in the right direction as they learn and develop new knowledge in the courseware.	This feature would provide appropriate feedback students need as they engage with the course materials. The just-in-time and targeted nature of the feedback that students get could positively impact their learning.
Embedded Summative Assessments	This feature provides embedded summative assessments throughout the courseware that are automatically graded by the system. The feature could save instructors a lot of time since they don't have to create their own assessments and grade them as they would normally do in traditionally taught courses. That time can be refocused on helping individual students who are struggling and/or supporting active learning work inside and outside the classroom time.	This feature would ensure that the assessments are closely aligned with the courseware content and therefore create more consistent and streamlined learning experience for students.
Real-Time Student Learning Data for Instructors	This feature allows instructors and other authorized users to access to an intuitive and interactive dashboard that continually collects, analyzes, and displays real-time data on student activity, engagement and performance. The readily	This feature would deepen students' learning experience by providing real-time learning data to instructors in a readily digestible format so they can target their in-

	digestible student learning data provided by the dashboard allows instructors to target their in-class instruction to meet students' learning needs throughout the semester.	class instruction and activities to address students' engagement and performance.
Real-Time Learning Data for Individual Students	This feature provides students access to an intuitive and interactive dashboard that displays real-time data on their own activity, engagement, and performance. The feature allows students to gain a deeper understanding of their own learning processes and make informed decisions where appropriate. It is designed in a way that motivates students to continually engage in the course while providing useful tips and resources when they most need them.	This feature would allow students to monitor their own learning processes and make appropriate decisions about which areas to devote more time and energy to improve their overall learning.
Time Management Tool for Students and Instructors	This feature allows students and instructors with information about anticipated time allocations for course activities, and a tool to schedule those activities. Time management is an important element of teaching and learning.	This feature would allow students to pace their learning and not fall behind on their progress in the course.
Study Resources Creator Tool for Students and Instructors	This feature allows students and instructor to create study resources (e.g., study guides, formula sheets) that can be downloaded for print and opened in a web browser or a mobile app for easy access.	This feature would allow students to create study guides that can be exported out from the courseware to further deepen their learning.

Product Organization

Table 2 illustrates a possible organizational structure of the product by larger units, modules and pages. The number of units may depend on the scope of the course. Each module is organized by a set of learning objectives that are covered in a series of pages via explanatory text, videos, and/or demonstrations. Each unit begins with a pre-assessment and personalized remediation and ends with a unit review and unit summative assessment. Based on student performance on the pre-assessment and formative exercises throughout the course, the system generates personalized learning pathways through adaptive practice, real-time feedback and system automated tutoring to individual students. The formative exercises are designed to provide ample opportunities for students to apply what they learn, practice and test their growing knowledge before getting to the summative assessment.

Table 2. A Possible Organizational Structure of Product

		Page 1	Pre-assessment and personalized remediation
Unit 1	Module 1 organized by a set of learning objectives	Page 2	Embedded, adaptive formative exercises with real-time feedback and automated tutoring
		Page 3	
		Page 4	
		Page 5	
		Page 6	Module quiz
	Module 2 organized by a set of learning objectives	Page 7	Embedded, adaptive formative exercises with real-time feedback and automated tutoring
		Page 8	
		Page 9	
		Page 10	
		Page 11	Module quiz
	Module 3 organized by a set of learning objectives	Page 12	Embedded, adaptive formative exercises with real-time feedback and automated tutoring
		Page 13	
		Page 14	
		Page 15	
		Page 16	Module quiz
	Module 4 organized by a set of learning objectives	Page 17	Embedded, adaptive formative exercises with real-time feedback and automated tutoring
		Page 18	
		Page 19	
		Page 20	
		Page 21	Module quiz
	Module 5 organized by a set of learning objectives	Page 22	Embedded, adaptive formative exercises with real-time feedback and automated tutoring
		Page 23	
		Page 24	
		Page 25	
		Page 26	Module quiz
		Page 27	Unit review
		Page 28	Adaptive practice test
		Page 29	Unit summative assessment

User Classes and Characteristics

Table 3 summarizes eight possible user classes who may use this product as well as the pertinent characteristics of each. The Teaching Assistant and Peer Tutor user classes may be considered optional depending on the institutional and/or student group needs.

Table 3. Possible User Classes and Characteristics

Possible User Classes	Characteristics
Program lead	Provides leadership and management at the system or state-wide level to ensure effective delivery of the course across multiple institutions; reviews aggregate data on student activity and performance for program improvement
Course design lead	Provides leadership on the curriculum, course design, content management, and course delivery in collaboration with design leads at other institutions under the supervision of the program lead; manages the course design process including making appropriate and timely updates to the course and instructor training materials
Systems administrator	Manages the process of integrating the courseware into the technological infrastructure of the institution; manages user profiles, roles, and access; manages data collection and integration
Academic advisor	Provides guidance to student on course and major selection and career planning; receives alerts if student activity or performance indicates potential withdrawal from course or risk of failing
Lead instructor	Teaches the hybrid class utilizing the courseware; serves as a guide and mentor to other instructors at the local institution and regularly interacts with lead instructors at other institutions teaching the same course(s); provides feedback to the program lead team for continuous improvement of the course and update to the training materials and the overall program
Instructor	Teaches the hybrid class utilizing the courseware; regularly checks in with other instructors at the local institution under the guidance of the lead instructor
Teaching assistant (optional)	Assists front-line instructors with the delivery of the course, including grading, facilitating discussion and study sessions, and responding to student inquiries
Peer tutor (optional)	Former students of the course who provide tutoring and advice to students currently enrolled in the course
Student	Student enrolled in the hybrid course utilizing the courseware

These users may be organized into three user class groups for purposes of permissions for individual campuses (Diagram 1). It is assumed that institutions within a consortium, system, or state that are using the courseware have similar sets of user classes, groups, and permissions so they can collaborate on course design/delivery, faculty training, content management as well as evaluation of student performance to ensure quality of instruction and scalability of the courseware package across multiple institutions.

Diagram 1. Possible User Class Groups and Select Permissions for Individual Campuses

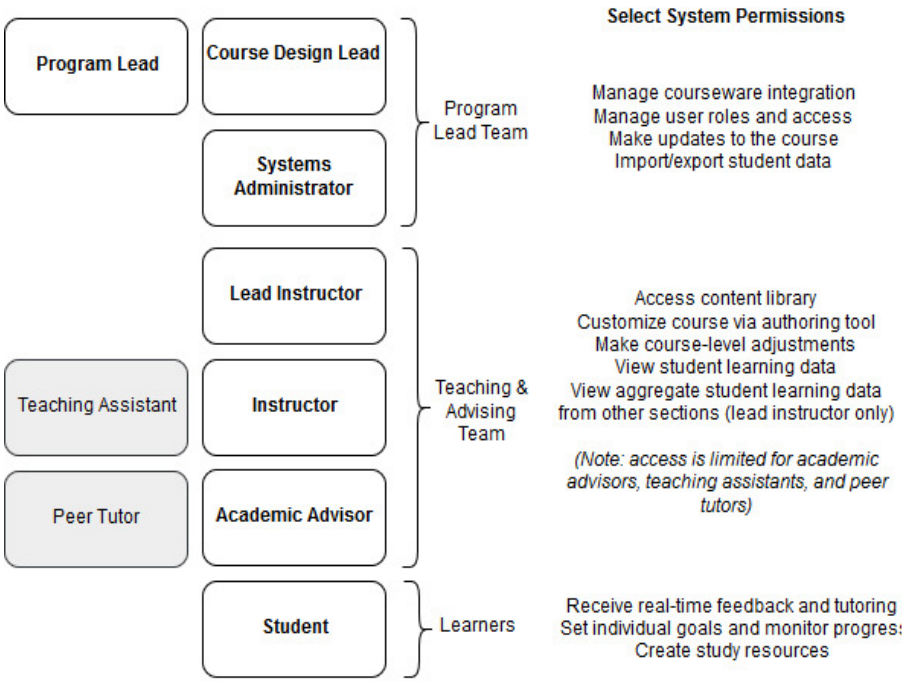
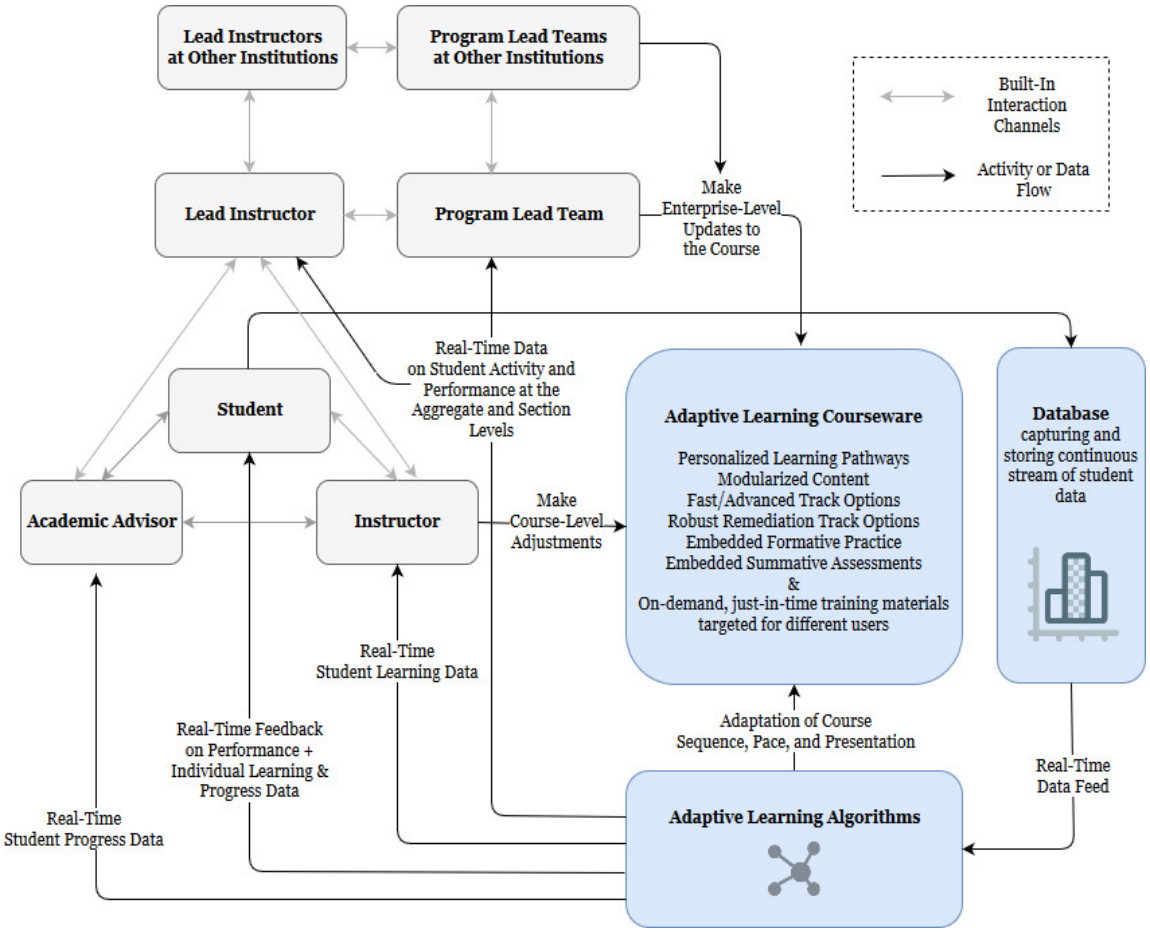


Diagram 2 depicts a possible organizational model for implementing adaptive learning course across multiple institutions. Note that the blue boxes represent the adaptive learning courseware package while the gray boxes represent key user classes/groups. The gray arrows represent built-in interaction (or communication) channels between the user classes/groups, and black arrows represent activity or data flow within the platform.

The synchronized, real-time activity and data flow allow students to take personalized learning pathways in the courseware while instructors and academic advisors get access to real-time student learning and progress data that they can rely on to make informed decisions in their instruction and advising. The lead instructors and program lead team(s) both within and across the institutions also get access to student activity and performance data both at the aggregate and section levels to make data-driven decisions when working collaboratively to make enterprise-level updates to the course to continually improve the content and delivery strategies.

Diagram 2: An Organizational Model for Implementing Adaptive Learning Courseware Across Multiple Institutions



Product Features

This section presents the core functional requirements for the product by system features and the major services provided by the product.

Pre-programmed Course Content Blocks

The courseware includes off-the-shelf course content (including appropriate activities and assessments) that is modularized to make it easy for designated enterprise-level users (e.g., program lead, course design lead) to create a course that is consistent with the institutional, state, and/or national standards and can address unique needs of different academic and pre-professional programs by simply switching on or off certain content modules or blocks. The courseware includes default settings permitting designated users -- the course design team -- to select from a menu of internally coherent

combinations of modules that align to the most common standards, scopes, and majors. The courseware also allows designated users to make ongoing modifications to the content at the enterprise level to ensure quality and consistency of the materials and to update them over time.

Functional Requirements

REQ-1: The courseware provides pre-programmed course content that is aligned with the major state and/or national standards and organized by their relevance to particular fields of study or career pathways for easy customization of the course for each institution or cohort of institutions.

REQ-2: The courseware includes default settings permitting designated users to select from a menu of internally coherent combinations of modules that align to the most common standards, scopes, and majors.

REQ-3: The courseware allows designated users to easily customize a course (remove, add, move existing content to another section, etc.) by simply switching-on or switching-off certain modularized content blocks.

REQ-4: The courseware alerts designated users if the customized course is not aligned with the appropriate institutional, state, and/or national standards.

REQ-5: The courseware provides tips and guidance to designated users who are customizing the course to ensure that the sequence and scope of the course are aligned with the recommendations made by the math pathways model so the course can support students' diverse academic and career pathways.

REQ-6: All learning outcomes are mapped to show direct correspondence to the requirements for students' further education and career advancement.

REQ-7: The courseware also allows designated users to make ongoing modifications to the content at the enterprise level to ensure quality and consistency of the materials and their relevancy over time.

REQ-8: The courseware includes a reporting function which allows designated users to generate reports with a detailed summary of each customized course (the scope and sequence of the course, learning outcomes covered, etc.) which may be shared with other stakeholders for portability of student credit across a range of institutions and for other decision making purposes.

Rich Content Library and Course Authoring Tool

The courseware has a rich content library through which instructors can access a variety of standalone problems, activities, and/or assessments (non-adaptive) that can be downloaded for use in a face-to-face classroom or inserted into the courseware through the course authoring tool. This feature is intended to provide some room for local creativity at the classroom or institutional level to support students with unique interests, goals, and needs. However, the optional content must not be added in a way that undermines the internal coherence or functionality of the course design selected at the enterprise level.

Functional Requirements

REQ-1: The content library materials are organized so they are aligned with the scope and sequence of the course for easy access and use.

REQ-2: The content in the library can be downloaded in multiple formats (e.g., Word, LaTex, etc.).

REQ-3: The content in the library can be inserted directly into the courseware and made available to students, with settings for scheduling the content and incorporating results into the system gradebook (which can integrate with gradebooks in common LMS's).

REQ-4: Optional content inserted directly into the courseware must not undermine the internal coherence or functionality of the course design selected at the enterprise level.

On-Demand and Just-in-Time Training Materials for Users

The courseware provides embedded training materials for students and instructors, some portions of which can be modified by designated users (i.e., program lead team). The training materials are composed of two parts: (1) those that are intended to help both students and instructors take full advantage of the features and functionalities afforded by the courseware to facilitate their learning and teaching, and (2) those that are intended to provide a comprehensive professional development and instructional resources to instructors or other teaching staff to readily adopt the concepts and pedagogical practices needed for implementation of the Pathways Model.

Functional Requirements

REQ-1: The courseware requires completion of a limited set of training materials to navigate the courseware (tailored for specific user type and their level of access within the system).

REQ-2: The training materials are modularized by topics and stored in a single location (tailored for specific user type) to allow users access to the materials on-demand.

REQ-3: The training materials are embedded within the courseware (tailored for specific user type). Appropriate training materials are suggested on each page at a consistent place on the page. These are intended to provide just-in-time support and training for all users.

REQ-4: The courseware allows designated users to create, add, or modify some portions of the training materials, particularly the ones pertaining to the pedagogy training and instructional resources package. The system also allows institutions to modify the materials based on the modality and facilities selected for course delivery (e.g., a computer lab vs. a lecture hall with students working on laptops or tablets).

Pre-Assessment and Personalized Remediation for Students

The courseware embeds course-specific pre-assessments in foundational math concepts and skills at appropriate points in the curriculum. The assessments trigger personalized developmental learning pathways that address students' areas of developmental need.

Functional Requirements

REQ-1: When students complete the assessment, the system presents the assessment results page that summarizes students' stronger and weaker skill areas.

REQ-2: Students can access personalized remediation from the assessment results page. This remediation is composed of focused explanations of the math concepts in students' weaker skill areas with helpful illustrations and guided practice and mini-quizzes to help students master the necessary skills. The closer this can come to automated tutoring, the better.

REQ-3: After students complete their remediation, the system provides them with other ways to seek help to strengthen their weaker skill areas – e.g., allowing them to share results or communicate with an on-campus or virtual tutoring center, a teaching assistant, and/or a peer tutor.

REQ-4: Students may not access a section of the standard curriculum until they complete both the assessment and the generated personalized remediation content for that section.

Embedded and Adaptive Formative Exercises for Students

The courseware contains embedded and adaptive formative exercises throughout the course to provide ample opportunities for students to practice and test their growing knowledge before getting to the graded summative assessments. Real-time feedback and automated tutoring feature is built into these exercises (see the resources on the Principles of Good Learning Assessment for further guidance).

Functional Requirements

REQ-1: The content and pedagogical approaches align with the recommendations outlined by the Math Pathways Model and CWiC Framework – e.g., focus on conceptual understanding and active learning.

REQ-2: The formative exercises reflect the nature of multiple educational and career pathways, ensuring that students have the opportunity to develop a range of generic skills and capabilities that are transferrable across multiple contexts.

REQ-3: The formative exercises effectively scaffold and measure student learning attainment of the intended learning objectives.

REQ-4: The courseware provides clear, accurate, and consistent information about exercises, tasks, and procedures to all users.

REQ-5: There are fast track and advanced learning options for students who have achieved mastery in the predefined learning objectives.

REQ-6: There are slower track options with robust automated tutoring and support for students who are struggling to achieve mastery in the predefined learning objectives.

REQ-7: The formative exercises that each student gets from the system collectively mirror the item formats and levels of rigor and difficulty featured in summative assessments.

REQ-8: The amount of assessed work required provides a reliable and valid profile of the progress students are making without overloading instructors or students.

REQ-9: Student learning data from the formative exercises are loaded to both instructor and student dashboards in easily interpretable formats.

REQ-10: The formative exercises presented to students are inclusive and equitable, ensuring that the presented tasks do not disadvantage any group or individual.

Real-Time Feedback and Automated Tutoring for Students

The courseware provides real-time feedback to student users as they go through formative exercises and practice tests in the form of a simple hint, video, graph or other additional resources based on how students perform and engage with the courseware content ((see the resources on Growth Mindset, Grit, and Resilience for their implications on feedback design).

Functional Requirements

REQ-1: The courseware is able to learn from both single and multiple inputs by student users and generate practice pages that are targeted for each student's needs.

REQ-2: The courseware is able to learn from both single and multiple inputs by student users and address any misconceptions they might have with additional explanation and help steer them toward deeper learning with additional resources.

REQ-3: The system is able to evaluate students' time spent on screen or number of question attempts to provide targeted feedback and support.

REQ-4: The feedback given to students in the platform incorporates strategies for promoting student motivation throughout the course.

REQ-5: Strategies to support students as independent learners are embedded throughout the courseware (e.g., modularized content, self-progress checks, targeted feedback, goal-setting activities, self-paced checkpoints and ample opportunities to practice before proceeding to take quizzes or tests)

REQ-6: There is an option to include a built-in communication channel between students, peer tutors, and/or other student support groups on campus. The system is able to integrate with other systems that are used by different groups on campus.

Embedded Summative Assessments

The courseware contains embedded summative assessments that appear after a series of formative adaptive exercises throughout the course content in the form of module quizzes and unit summative tests that are automatically graded and get recorded on the

course gradebook (see the resources on the Principles of Good Learning Assessment for further guidance).

Functional Requirements

REQ-1: The summative assessments reflect the nature of multiple educational and career pathways.
REQ-2: The summative assessments effectively measure student learning attainment of the intended learning objectives.
REQ-3: The courseware provides clear, accurate, and consistent information about assessment tasks and procedures to all users.
REQ-4: The summative assessments presented to students mirror what was covered in the preceding unit and/or module in terms of format, rigor and difficulty level.
REQ-5: The summative assessments presented to students are inclusive and equitable, ensuring that they do not disadvantage any group or individual.

Real-Time Student Learning Data for Instructors

The courseware provides instructors and other authorized institutional users access to an intuitive, interactive dashboard including real-time data on student activity, engagement, and performance.

Functional Requirements

REQ-1: Instructors and other designated users have access to a dashboard that serves as a portal through which they can access all information regarding student activity, engagement, and performance.
REQ-2: Instructors or other designated users can assign particular users (e.g., teaching assistants) to access student assessment data for instructional purposes.
REQ-3: The dashboard data are organized in ways that allow for easy analysis and interpretation (e.g., interactive graphs or charts).
REQ-4: The dashboard allows instructors to visualize student engagement and performance data at multiple levels – i.e., at the course unit level, module level, exercise level, assessment level, class level, and individual student level.
REQ-5: The dashboard includes analyses mapping individual students' activity and performance to content and learning outcomes, allowing instructors to understand the activities and topics in which each student is

performing better or worse, and these data can be aggregated at multiple levels – i.e., at the unit level, module level, assignment level, assessment level, class level, and individual student level.

REQ-6: The dashboard highlights areas that require instructors' attention and provides tips on how to motivate student engagement either in class or outside of class (e.g., office hours).

REQ-7: The dashboard is connected to the study resource creator tool, which allows instructors to create study guides for students based on the summary of their dashboard data.

REQ-8: Student-level data collected in the platform are amenable to aggregation and reporting which allow departments, programs, institutions, policymakers, or other stakeholders to track course-wide student progress.

REQ-9: The courseware permits assignment of an appropriate level of access to student-level data to partner organizations such as community colleges and K-12 schools.

Real-Time Student Learning Data for Students

The courseware provides students access to an intuitive, interactive dashboard which includes real-time data on their own activity, engagement and performance.

Functional Requirements

REQ-1: Individual students have access to a dashboard that serves as a portal through which they can access all information regarding their own activity, engagement, and performance in the courseware.

REQ-2: The dashboard data are organized in ways that allow for easy analysis and interpretation (e.g., interactive graphs or charts).

REQ-3: The dashboard allows students to visualize their engagement and performance data at multiple levels – i.e., at the course unit level, module level, exercise level, assessment level, and learning objective level.

REQ-4: The dashboard highlights students' weaker and stronger skill areas within the course and provides tips for strengthening weaker skill areas.

REQ-5: The dashboard is connected to the study resource creator tool, which allows students to create study guides based on the summary of their dashboard data.

Time Management Tool for Students and Instructors

The courseware provides students and instructors with dynamic information about anticipated time allocations for course activities, and a tool to schedule those activities.

Functional Requirements

REQ-1: There is a common calendar that all students can access which has all of the critical due dates and deadlines that are unique to the course (e.g., assignment and quiz/test due dates) and the institution (e.g., add-drop deadline, institutional holidays).
REQ-2: The users can also set frequencies for getting reminder notifications via email or text message.
REQ-3: The course-level calendar can sync with other types of online calendars outside of the system (e.g., Google, iCal, Outlook).
REQ-4: Each module and unit has a progress bar to help students track where they are in terms of completing a module or unit.
REQ-5: The courseware allows students to set their own learning goals and track their progress toward achieving each of the goals.
REQ-6: The courseware provides estimated time requirements for course activities.

Study Resources Creator Tool for Students and Instructors

The courseware allows students and instructors to create study resources (e.g., study guides, formula sheets) that can be downloaded for print and opened in a web browser or a mobile app for easy access.

Functional Requirements

REQ-1: The courseware allows students and instructors to create study guides that can be downloaded for print or opened in a web browser or mobile app.
REQ-2: The courseware allows students to only use content that they have already completed when creating their study resources.
REQ-3: The courseware provides summary performance data to both instructors and their students (similar to what they see in the dashboard) to guide the study resources creating process.

Conclusion

Developing a product that captures all – or even most – of the features listed as "requirements" in this document is clearly ambitious, but our experience with the ALiS course as well as previous work in this area suggest that getting close to this goal is critical if we want to have any chance of really moving the needle on student success rates in a gateway math course. Moreover, based on our experience with the ALiS course, we feel strongly that instructors' understanding of and commitment to a new mode of teaching is as important as the quality and accessibility of the courseware being used. As exciting as the concept of adaptive learning may be, it is still the individual instructor and his/her teaching team who makes the biggest difference in terms of student engagement and performance, and how well those instructors are trained and supported is perhaps one of the most important determinants of whether or not we can significantly improve student outcomes. In other words, having the right tools and resources essential, but equally important is the commitment of both institutional leaders and instructors to embrace the pedagogical opportunities and challenges those tools open up.

With this note, we end this document with three recommendations that courseware providers would want to consider when looking to develop a long-term partnership with a large number of institutions to develop and deliver a courseware package that has the potential to improve student outcomes.

Recommendation 1. *Be a Thought Partner.*

- Gain a clear understanding of the problem and why the change is needed from the perspective of the institutions and their constituents and make that drive the product development process.
- Be willing to involve institutional leaders and potential users at appropriate times during the product development process to help shape the overall framework and direction.
- Participate in ongoing discussions with institutional stakeholders to figure out how and in what ways the product could be designed and delivered to meet their intended goals and outcomes.

Recommendation 2. *Provide Robust Onboarding Support.*

- Work closely with institutional leaders, faculty and instructional designers to modify the courseware to reflect local needs and priorities.
- Work closely with institutional leaders, faculty and instructional designers to develop and maintain a comprehensive faculty professional development program that encompasses both the technical and pedagogical guidance along

with high quality instructional resources to help faculty and others engage in evidence-based teaching.

- Be prepared to test and revise the courseware as well as the plans and processes for implementation through a series of pilot tests.

Recommendation 3. *Collaborate on Evaluation to Continually Improve.*

- Share the data from the platform and work with institutional stakeholders on a plan for analysis in order to evaluate the impact of the intervention and help inform their ongoing decisions about how to improve their practices and outcomes.
- Be willing to continually redesign and refine the product to better meet the institutions' and users' evolving needs.
- Be prepared to think about new ways to price the product.

Annotated Resources List

Guided Pathways

1. Achieving the Dream, American Association of Community Colleges, Charles A., Dana Center, Complete College America, Education Commission of the States, and Jobs for the Future (2015). Core Principles for Transforming Remediation within a Comprehensive Student Success Strategy [A joint statement]. Retrieved from https://www.insidehighered.com/sites/default/server_files/files/core_principles_nov5.pdf.

   This joint statement urges institutions to rethink efficacy of their orientation, advising, placement, and remediation education policies and practices in order to facilitate expansion of educational access to all students, especially those that are low-income or from historically underserved communities. The authors present the following six common elements of diverse strategies that are showing great promise as core principles for transforming remediation:
   - Every student's postsecondary education begins with an intake process to choose an academic direction and identify the support needed to pass relevant credit-bearing gateway courses in the first year
   - Enrollment in college-level math and English courses or course sequences aligned with the student's program of study is the default placement for the vast majority of students.
   - Academic and nonacademic support are provided in conjunction with gateway courses in the students' academic or career area of interest through co-requisite or other models with evidence of success in which supports are embedded in curricula and instructional strategies.
   - Students for whom the default college-level course placement is not appropriate, even with additional mandatory support, are enrolled in rigorous, streamlined remediation options that align with the knowledge and skills required for success in gateway courses in their academic or career area of interest.
   - Every student is engaged with content of required gateway courses that is aligned with his or her academic program of study—especially in math.
   - Every student is supported to stay on track to a college credential, from intake forward, through the institution's use of effective mechanisms to generate, share, and act on academic performance and progression data.

2. Complete College America (CCA). (2012). *Remediation: Higher Education's Bridge to Nowhere*. Complete College America, Washington, District of Columbia. Retrieved from https://www.insidehighered.com/sites/default/server_files/files/CCA%20Remediation%20ES%20FINAL.pdf.

   The authors present four steps that states can take to close "remediation exit ramps":
   - *Strengthen high school preparation* – reduce the need for college remediation by adopting and implementing common core state standards in

reading, writing and math and align requirements for entry-level college courses with requirements for high school graduation; administer college-ready anchor assessments in high school and use them to develop targeted interventions before students fall too far behind.

- *Start students in college-level courses with built-in, co-requisite support* – place freshmen students with basic needs immediately into entry-level, credit-bearing college courses with co-requisite support; make the course into two-semester courses for students needing more support with built-in tutoring; in the meantime, offer students with significant academic skill certificate programs with embedded remediation
- *Embed needed academic help in multiple gateway courses* – help students get a strong, early start by building extra supports around all of the early gateway courses that are necessary for success in students' fields of study
- *Encourage students to enter programs of study when they first enroll* – students are twice as likely to graduate if they complete at least three courses in their chosen programs of study in their first year on campus; create clear, limited, and structured program pathways containing core college-level courses; early college-level courses required in their programs of study should have embedded help

3. Hodara, M., Jaggars, S. S., & Karp, M. M. (2012). Improving Developmental Education Assessment and Placement: Lessons from Community Colleges across the Country. CCRC Working Paper No. 51. Community College Research Center, Columbia University. Retrieved from https://ccrc.tc.columbia.edu/media/k2/attachments/developmental-education-assessment-placement-scan.pdf.

   The authors describe a variety of approaches that select open-access two-year colleges in Georgia, New Jersey, North Carolina, Oregon, Texas, Virginia, and Wisconsin employed to ameliorate poor course placement accuracy and inconsistent standards of college readiness. They advocate for *multiple measures approach,* which could potentially have greater longer-term academic success of community colleges, to replace traditional approaches that rely heavily on a single measure (i.e., standardized placement exams that measure English and mathematical skill levels). Here are some examples of multiple measures approach:

   - Non-cognitive assessment at a Wisconsin technical college: Non-cognitive factors include weakness in degree choice, a lack of social support, financial concerns, and self-efficacy. The school incorporated a new assessment based on the *Learning and Study Strategies Inventory (LASSI)* which assesses students' awareness about the use of learning and study strategies related to skill, will, and self-regulation components of strategic learning.
   - Multiple measures at a University of Wisconsin two year college: The school introduced a writing sample to supplement the multiple-choice English placement exam and worked with student services to assess and review students' ACT scores, high school grades, class rank, math placement scores, and TRIO eligibility. The school also added a survey that asks incoming students about their high school curriculum, how long they have been out of school, and their home language. Faculty review each student's profile of multiple measures at the beginning of each semester to make course recommendations.

- Student self-placement at Oregon community college: The school requires students to take a customized math placement test, but faculty regard the exam as only "a guideline" in terms of students' placement. An advisor or math faculty reviews the results in consultation with individual students to help them make their own choice in terms of first semester math coursework. In so doing, they are leveraging multiple sources of information – student performance on the math placement exam, advisor or math faculty experience and judgement, and students' own self-knowledge of their math preparedness.

4. Jenkins, D. (2014). Redesigning community colleges for student success: Overview of the guided pathways approach. Community College Research Centre (CCRC). Retrieved from http://www.mcca.org/uploads/ckeditor/files/DavisJenkins_CCRC_Guided%20Pathways%20Overview_Revised%20Oct%202014%281%29.pdf. (also see Bailey, T., Jaggars, S., 6. Jenkins, D. (2015) Redesigning America's Community Colleges: A clearer path to student success. Cambridge, MA: Harvard University Press.)

   The author provides an overview of the barriers to student success created by the way most community colleges are currently organized. The paper also describes the key design features of the guided pathways model, the process for implementing it as well as the reasons why college leaders should considering doing it despite the costs involved. At the end of the paper, the author also presents a few case studies of select institutions that have implemented guided pathways at scale.

5. Johnstone, R. (2015). Guided pathways demystified: Exploring ten commonly asked questions about implementing pathways. National Center for Inquiry and Improvement. Retrieved from https://dcmathpathways.org/sites/default/files/resources/2017-03/PWs-Demystified-Johnstone-110315.pdf.

   The movement so called "guided pathways" is gaining more traction from education communities as a promising way to ensure that more students can achieve their educational goals and earn family sustaining wages. Multiple efforts are taking place across the country to implement the guided pathways approach at scale, including the Bill and Melinda Gates Foundation's *Completion by Design (CBD)* initiative, the Lumina Foundation's *Guided Pathways to Success (GPS)* initiative, the Kresge Foundation's *Pathways* projects, as well as the *Texas Completes* initiative. The guided pathways approach operates under the premise that highly structured student experiences can encourage successful and on-time completion by: establishing clear roadmaps to students' end goals that include articulated learning outcomes and direct connections to the requirements for further education and career advancement; incorporating intake processes that help students clarify goals for college and careers; offering on-ramps to programs of study designed to facilitate access for students with developmental education needs; and embedding advising, process tracking, feedback, and support throughout a student's educational journey (Jenkins & Choo, 2014, Bailey, Jaggers, & Jenkins, 2015 as cited in Johnstone, 2015, p. 2). The author addresses top ten questions and concerns about guided pathways with the goal of informing higher education leaders who are interested in attempting to implement guided pathways but may be encountering push-back from peers or are tentative about such movement taking place on their own campus.

6. Saxe, K. & Braddy, L. (2015). A common vision for undergraduate mathematical sciences programs in 2025 [A report by the Mathematical Association of America]. Retrieved from https://www.maa.org/sites/default/files/pdf/CommonVisionFinal.pdf.

   Under the initial phase of the Common Vision project, leaders from five professional associations – the American Mathematical Association of Two-Year Colleges (AMATYC), the American Mathematical Society (AMS), the American Statistical Association (ASA), the Mathematical Association of American (MAA), and the Society for Industrial and Applied Mathematics (SIAM) – came together to collectively reconsider undergraduate curricula and brainstorm ways to improve education in the mathematical sciences. Upon doing an in-depth examination of the curricular guides published by the five associations, they identify areas that require significant action from the mathematical sciences community to improve undergraduate learning. They urge the community to update curricula to meet the changing needs of the society, articulate clear pathways between curricula at the K-12 level and the first set of courses students take in college, scale up the use of evidence-based pedagogical methods, find ways to remove barriers facing students, and establish stronger connections with other disciplines.

New Math Pathways

7. *Dana Center Math Pathways Call to Action: The Case for Mathematics Pathways* (October 2016) retrieved from https://dcmathpathways.org/sites/default/files/resources/2016-11/The%20Case%20for%20Mathematics%20Pathways.pdf.

   The authors argue that traditional mathematics courses have been the most significant barrier to degree completion for students in all fields of study, especially for minority and underrepresented students. They make the case that a mathematics pathways solution can significantly increase student success by addressing two structural drivers of the problem, namely the (1) mismatch of content (traditional entry-level math not aligned with students' mathematical needs) and (2) long, multi-semester developmental course sequences that decrease students' chances of completing a credit-bearing math course. The authors cite research findings from several initiatives that have developed and implemented co-requisite models (i.e., students with developmental needs in math are directly placed in credit-bearing courses and are provided with robust support along the way to help them earn their credits within a semester or a year) have shown that underprepared students can succeed in college-level math courses at higher rates and in less time as compared to those in traditional developmental sequences (Bailey et al., 2010; California Acceleration Project, 2015; Complete College America, 2016; Rutschow & Diamond, 2015; Sowers & Yamada, 2015).

8. *The Joyful Conspiracy* presented by Professor Uri Triesman at a meeting hosted at Greenfield Community College which was co-sponsored by New England College Council (NECC) on April 26, 2013. Retrieved from https://www.youtube.com/watch?v=yVMhCH8WFZI.

Professor Treisman discusses the challenges of improving student success through reform of developmental and gateway mathematics programs. He provides a national perspective on reform and makes a case for working at scale in new ways.

9. *Big Ideas for Scaling the New Mathways Project* by Jenna Cullinane, a presentation on strategies for scaling innovations and the ideas guiding the work to scale the New Mathways Project in Texas at Achieving the Dream's 2013 Annual Meeting on Student Success on February 7, 2013 at Anaheim, CA. retrieved from https://www.youtube.com/watch?v=QGDwey_MEpQ (also see a short written piece here)

10. *Guide to Aligning Mathematics Pathways to Programs of Study* developed by the Dana Center. Retrieved from https://dcmathpathways.org/resources/guide-aligning-mathematics-pathways-programs-study.

    This guidebook can be used as a tool to help align math pathways to programs of study.

11. *Sample Math Pathways List* developed by MDRC in collaboration with the Dana Center. Retrieved from https://dcmathpathways.org/sites/default/files/resources/2017-05/Sample%20Math%20Pathways%20List.pdf

    This resource can be used in conjunction with the *Guide to Aligning Mathematics Pathways to Programs of Study* document or as a separate resource. The list shows how different institutions aligned math pathways with their programs. Information was compiled from the Dana Center's *Mathematics Pathways Transfer Inventory* with specific focus on math requirements at several four-year colleges and community colleges in Texas that are well aligned with the math pathways model. Readers should note that this is intended only as a reference as each school context is different and unique.

12. *Indiana Math Innovation Council Recommended Gateway Math for Meta-Majors* retrieved from https://dcmathpathways.org/sites/default/files/2016-08/Indiana%20Meta-Majors%20List.pdf.

    In 2014, in collaboration with Complete College America and the Dana Center, math faculty from all public institutions in Indiana and institutional research representatives came together to form Indiana Math Innovation Council with the goal of increasing success rates in gateway courses without compromising the integrity of mathematics and aligning mathematics requirements to the competencies required for academic and career success. This document shows the council's recommended gateway math for different meta-majors.

13. *Proposed Indiana's College & Career Ready High School Diploma* retrieved from http://www.in.gov/che/files/150813_Proposed_Indiana_High_School_Diploma.pdf.

    This proposed draft Indiana High School Diploma was shared at the Meta-Majors and Math Pathways Convening on September 1, 2015 in Indianapolis, IN. This is an

example of aligning requirements for entry-level college courses with requirements for high school graduation.

14. Carnegie Foundation for the Advancement of Teaching's *Statway Fact Sheet* retrieved from https://www.carnegiefoundation.org/wp-content/uploads/2017/06/sw_one_pager_June17.pdf.

    This compact fact sheet describes what Statway is, why institutions should adopt it as part of their math curricula, why faculty should join the network, and how it was developed and designed.

15. Carnegie Foundation for the Advancement of Teaching's Quantway 1 Fact Sheet retrieved from https://www.carnegiefoundation.org/wp-content/uploads/2017/06/qw1_one_pager_June17.pdf.

    This compact fact sheet describes what Quantway 1 is, why institutions should adopt it as part of their math curricula, why faculty should join the network, and how it was developed and designed.

16. Huang, M. (2018). 2016-2017 Impact Report: Six Years of Results from the Carnegie Math Pathways™. San Francisco, CA: WestEd. Retrieved from *https://www.carnegiefoundation.org/wp-content/uploads/2018/04/Pathways_Descriptive_Report_201802.pdf.*

    This report provides descriptive statistics for 2016-2017 student outcomes as well as insights into potential areas of improvement, based on data from the Carnegie Statway and Quantway 1 Pathways' six year of implementation across a range of institutions. The results show that both Pathways continue to deliver three to four times the success rate of traditional pathways in half the time. It is important to note that the Pathways managed to uphold these good results while expanding its scale to a diverse range of contexts.

Adaptive Learning Technology

17. Moskal, P., Carter, D., and Johnson D. (2017). 7 Things You Should Know About Adaptive Learning. EDUCAUSE Learning Initiative (ELI). Retrieved from https://library.educause.edu/~/media/files/library/2017/1/eli7140.pdf.

    This document summarizes seven things people should know about adaptive learning in an engaging format.
    1) Adaptive learning systems use a data-driven—and, in some cases, nonlinear—approach to instruction and remediation.
    2) The systems "learn" from student interactions and then adjust the path and pace of learning.
    3) Adoption of these tools varies from individual instructors to institution-wide implementations.
    4) For institutions, adaptive learning enables the delivery of personalized learning at scale.
    5) It requires detailed curriculum mapping and content development.

6) Adaptive learning systems will improve as data are collected on more students over time.
7) Particularly for high-enrollment classes, adaptive learning can provide tailored support and guidance to all students.

18. Alli, N., Rajan, R., & Ratliff, G. (2016). How Personalized Learning Unlocks Student Success. EDUCAUSE Review Online. Retrieved from https://er.educause.edu/~/media/files/articles/2016/3/marapr16erfullissue.pdf?la=en.

    The authors make the case for the high potential adaptive learning technology has in unlocking student success in today's increasing diverse higher education landscape. The authors describe what personalized learning is and what they have learned from some of their grantees' ongoing work involving analytics to optimize student success. The authors also discuss about the importance of organizational strategy and change management to support institutions' capacity building with personalized learning technology.

19. Tyton Partners "Learning to Adapt 2.0: The Evolution of Adaptive Learning in Higher Education," April 2016. http://tytonpartners.com/library/learning-to-adapt-2-0-the-evolution-of-adaptive-learning-in-higher-education/.

    Interviews with leaders from over 20 institutions about their experiences with adaptive learning and survey responses from 35 suppliers with adaptive solutions in the market have revealed many difficult challenges that relate to integration of adaptive learning systems into existing institutional infrastructure and to the organizational and academic workflows of the institutions.

    The authors identified five themes that characterize the evolution of adaptive learning landscape, ranked from 1 (changed little since 2012) to 5 (changed significantly since 2012):
    1) While institutions have more experience with learning through product pilots, the path to broader implementation is uncertain;
    2) Applications of adaptive learning technology are expanding
    3) The role of faculty is changing with the emergence of "adaptive learning"
    4) Adaptive learning is a relevant option for competency-based education, but only in specific use cases and
    5) Adaptive products are building new feature sets in response to institutional demand.

20. A 2015-16 pilot study at the University of California (UC) exploring the use of adaptive learning technology (the Assessment and Learning Knowledge Spaces – ALEKS) funded by Bill and Melinda Gates Foundation. Retrieved from https://www.ucop.edu/institutional-research-academic-planning/_files/BFI-Adaptive-Learning-Technology-Report.pdf.
    This report presents findings from a 2015-2016 pilot study involving implementation of ALEKS system at three UC campuses (UC Davis, UC Santa Barbara, and UC Santa Cruz) in their select mathematics and chemistry courses. Overall, all three campuses found that when ALEKS was used by students "as intended," results were positive in relation to their overall performance in the course. In some cases, the same positive results were found in at-risk populations

(i.e., URM, low-income and first-generation students). The researcher note that, although their analyses revealed positive findings, ALEKS is not a simple panacea for poor student performance and that it requires institutions to adopt strategic objectives that take into account all facets of their organizational structures including, but not limited to, research, technology, finance and accountability. The report ends with eight recommendations based on their lessons learned from this study to inform ongoing investigations into the efficacy of adaptive learning in the context of campus academic programs intended to support student success and improve instruction.

21. EdSurge (2016). Decoding Adaptive, London: Pearson. Retrieved from https://www.pearson.com/content/dam/one-dot-com/one-dot-com/global/Files/about-pearson/innovation/Pearson-Decoding-Adaptive-v5-Web.pdf.

    In an effort to contribute to a common understanding and definition of adaptive learning technologies, the authors ask three main questions in this report: (1) What is adaptive learning? (2) What's inside the adaptive learning black box? (3) And how do the tools on the market differ? The authors present a definition and a framework for understanding the different ways a tool might be adaptive based on their research.

22. APLU Personalized Learning Consortium (2017). Implementing Adaptive Courseware: A Guide to Courseware Development, Use and Evaluation Based on the Collaborative Experience of Four Public Research Universities. Retrieved from http://www.aplu.org/library/implementing-adaptive-courseware-a-guide-to-courseware-development/file. (Also read about APLU's Adaptive Courseware Program overview, goals, participating institutions, and their progress reports here: http://www.aplu.org/projects-and-initiatives/personalized-learning-consortium/plc-projects/plc-adaptive-courseware/program-overview.html).

    This report is based on APLU Personalized Learning Consortium's English Composition Adaptive Courseware Development project in four public research universities (Georgia State University, Montclair State University, University of Georgia, and University of Mississippi) which aimed to educate faculty about recent innovations in adaptive learning technologies and support cross-institutional faculty collaboration in the development of adaptive learning modules for use in English composition instruction. The report identifies the key steps involved in launching a courseware development project and how this type of project might be used to engage faculty, department heads, and academic affairs leaders in thinking critically and creatively about the use of the adaptive courseware to personalize learning for English composition students.

23. Yarnall, L., Means, B., & Wetzel, T. (2016). Lessons learned from early implementations of adaptive courseware. *SRI Education. Retrieved from* https://www.sri.com/sites/default/files/brochures/almap_final_report.pdf.

    This report by SRI Education presents results from the Bill & Melinda Gates Foundation's Adaptive Learning Market Acceleration Program (ALMAP) between summer 2013 through winter 2015 in which 14 higher education institutions were given some seed funding to incorporate nine adaptive learning products into 23

courses and conduct quasi-experiments to measure their effects on student outcomes and gather data on cost impacts and instructor and student satisfaction.

Growth Mindset, Grit, and Resilience

24. Visit https://www.mindsetworks.com to learn more about Dr. Carol Dweck's work on growth mindset and how school interventions focused on cultivating students' growth mindset can close the achievement gap, reduce stereotype threat in classrooms, and reduce aggression and bullying. Although the interventions highlighted here have mostly focused on K-12 contexts, the lessons learned can also apply to higher education learning contexts. The mindset research shows that people's theories about their own intelligence can have a significant impact on their motivation, effort, and approach to challenges. For example, those who believe their abilities are malleable are more likely to embrace challenges and persist despite failure (see Dweck & Legett, 1988; also Dweck's book on "Mindset: The New Psychology of Success"). Dweck and her colleagues have shown that when students are taught that intelligence is malleable and shown how the brain grows with effort their grades significantly improved.

25. In an interview with The Atlantic (December 16, 2016), Carol Dweck calls for a more nuanced understanding of the "growth mindset." Dweck talks about a recently noticed trend – a widespread embrace of "false growth mindset" – with a misunderstanding of the idea's core message. Dweck explains that the oversimplification of growth mindset into just being about "effort" doesn't really help motivate students to explore new approaches to overcoming challenges they are facing. The growth mindset praise should focus on the "learning process" not simply on "effort." Dweck urges teachers and parents to focus on "process praise" – focus on the learning process and show how hard work, good strategies, and good use of resources can lead to better learning.

26. Watch this Stanford+Connects micro lecture by Carol Dweck on *Developing a Growth Mindset*: https://www.youtube.com/watch?v=hiiEeMN7vbQ.

27. Watch this TED talk by Carol Dweck on *The Power of believe that you can improve:* https://www.youtube.com/watch?v=hiiEeMN7vbQ.

28. Also learn more about Angela Lee Duckworth's work on grit by visiting https://angeladuckworth.com. Read more about her research here and the measures used to assess grit. Also watch her TED talk on *The Power of Passion and Perseverance*: https://www.youtube.com/watch?v=H14bBuluwB8\.

Courseware-in-Context (CWiC) Framework

29. The CWiC framework is intended to support postsecondary decision-makers in effectively navigating the market of courseware solutions. It is designed to help institutional decision-makers to make better-informed adoption and implementation decisions with the goal of advancing the adoption of high-quality

digital courseware in higher education and achieving improved outcomes for students. Learn more about the framework here: http://coursewareincontext.org/.

- A short video which gives an overview of the CWiC framework: https://www.youtube.com/watch?v=g-LIHj3sVnA.
- The full CWiC framework and evaluation instruments can be downloaded from here: http://coursewareincontext.org/thank-you/?fID=tile&pID=135.
- Courseware adoption checklist is a self-assessment tool to help courseware decision-makers determine their degree of readiness to make a courseware adoption decision. This can be used after the decision to adopt courseware has been made and in conjunction with close evaluation of one or more products: http://coursewareincontext.org/cwic-wp/wp-content/uploads/2017/09/TYT053_CWiC_Upd_Checklist_Rd2.pdf.
- The CWiC website also houses a collection of empirical studies and review papers that are tagged to product capabilities built into the framework. The studies in this collection involve a broad range of implementation practices and institutional conditions: http://coursewareincontext.org/research-collection/

Principles of Good Learning Assessment

30. American Association of Higher Education's *Principles of Good Practice for Assessing Student Learning* (December 1992). Retrieved from http://www.learningoutcomesassessment.org/PrinciplesofAssessment.html.

    The purpose of this document is (1) to provide a set of helpful "wisdom of practice" that campuses can use to examine current practice and for developing and discussing their own principles and (2) to support campus assessment leaders in their work with the administrators, policy makers, and legislators who often set the conditions that determine whether assessment will lead to real improvement. The authors of this statement are 12 practitioner-students of assessment as it has developed on campuses and some extent at the K-12 level. The core value behind this document is the importance of improving student learning and implicit in the principles is a vision of education that entails high expectations for all students, active forms of learning, coherent curricula, and effective out-of-class opportunities. The nine principles of good practice for assessing student learning are as follow:

    - The assessment of student learning begins with educational values.
    - Assessment is most effective when it reflects an understanding of learning as multidimensional, integrated, and revealed in performance over time.
    - Assessment works best when the programs it seeks to improve have clear, explicitly stated purposes.
    - Assessment requires attention to outcomes but also and equally to the experiences that lead to those outcomes.
    - Assessment works best when it is ongoing, not episodic.
    - Assessment foster wider improvement when representatives from across the educational community are involved.
    - Assessment makes a difference when it begins with issues of use and illuminates questions that people really care about.
    - Assessment is most likely to lead to improvement when it is part of a larger set of conditions that promote change.

- Through assessment, educators meet responsibilities to students and to the public.

31. Office of Educational Technology at the United States Department of Education's report on *Reimagining the Role of Technology in Higher Education* (January 2017) retrieved from https://tech.ed.gov/files/2017/01/Higher-Ed-NETP.pdf.

    This report is an outgrowth of the 2016 National Education Technology Plan (NETP). Building on the work of leading education researchers; state, district, school, and higher education leaders; teachers; developers; entrepreneurs; and nonprofit organizations, the NETP recommends actions that would enable everywhere, all-the-time learning and ensure greater equity and accessibility to learning opportunities over the course of a learner's lifetime. The report lays out 10 design principles for a student-centered higher education ecosystem (see pages 10-11), and recommendations for transforming the ecosystem in the following three domains: learning, teaching, and assessment. Read pages 38-45 about how assessments enabled by technology can better capture student learning process and help improve learning outcomes and instructional practices. Below are the 10 principles that can guide stakeholders envisioning and creating an expanded, student-centered higher education ecosystem:
    - Guide students toward education that enables them to achieve their goals, is suitable to their needs, and aligns with their interests
    - Help students make wise financial decisions about postsecondary education, including through transparent information about outcomes and return on investment
    - Prepare students for postsecondary-level work by redesigning diagnostic tools and providing adaptive, targeted learning solutions
    - Allow students to adjust the timing and format of education to fit other priorities in their lives
    - Provide students with affordable access to the high-quality resources they need to be successful and to empower them to become curators of their own learning
    - Enable advisors to help students to progress through times of transition and changing needs, leveraging technology such as data dashboards and texting where appropriate
    - Collect and use real-time learning data to provide targeted assistance to students
    - Allow students to build meaningful education pathways incrementally that allow them to move fluidly in-and-out of and between institutions to accommodate their learning and life goals
    - Allow students to document their learning in portable ways that can be applied to their further education or meaningful work
    - Create a network of learning that support students as creators and entrepreneurs, and agents of their own learning over their lifetimes

32. *Principles for Effective Assessment of Student Achievement* by national higher education associations and regional accrediting commissions (July 19, 2013) retrieved from http://www.learningoutcomeassessment.org/documents/EndorsedAssessmentPrinciples_SUP.pdf.

The statement contained in this document grew out of a meeting of the presidents of the seven regional accrediting commission and public and private university provosts. The statement emphasizes the need to assess effectively student achievement, and the importance of conducting assessments in ways that are congruent with the institution's mission. Federal law requires that a higher education institution undergoing accreditation provide evidence of "success with respect to student achievement in relation to the institution's mission." While the exact methods for measuring student success may be different for different institutions, all institutions should be expected to provide evidence of success in the following three domains:

- *Evidence of the student learning experience*: define and evaluate *how* students are learning
- *Evaluation of student academic performance*: define meaningful curricular goals; appropriate methods for the assessment of student work may include meaningful and rigorous faculty evaluation and grading or external benchmarking
- *Post-graduation outcomes: articulate how students will be prepared consistently with their mission for successful careers, meaningful lives, and, where appropriate, further education; collect and provide data which may include completion rates, job placement rates, levels of post-graduation civic participation, kinds of jobs and vocations chosen, surveys pertaining to alumni satisfaction and success, etc.*