Student-Centered Learning:

Functional Requirements for Integrated Systems to Optimize Learning

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MAY 2016

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iNACOL

The mission of the International Association for K–12 Online Learning (iNACOL) is to catalyze the transformation of K-12 education policy and practice to advance powerful, personalized, learner-centered experiences through competency-based, blended and online learning. iNACOL is a non-profit organization focusing on research, developing policy for student-centered education to ensure equity and access, developing quality standards for emerging learning models using competency-based, blended and online education, and supporting the ongoing professional development of classroom, school, and district leaders for new learning models. Learn more at www.inacol.org.

Glowa, L. and Goodell, J. (2016) *Student-Centered Learning: Functional Requirements for Integrated Systems to Optimize Learning* Vienna, VA.: International Association for K-12 Online Learning (iNACOL).

Table of Contents

Section I: Student-Centered Learning

The realities of the 21st-century learner require that schools and educators fundamentally change their practice. “Educators must produce college- and career-ready graduates that reflect the future these students will face. And, they must facilitate learning through means that align with the defining attributes of this generation of learners.”[1]

Today, we know more than ever about how students learn, acknowledging that the process isn’t the same for every student and doesn’t remain the same for each individual, depending upon maturation and the content being learned. We know that students want to progress at a pace that allows them to master new concepts and skills, to access a variety of resources, to receive timely feedback on their progress, to demonstrate their knowledge in multiple ways and to get direction, support and feedback from—as well as collaborate with—experts, teachers, tutors and other students.

The result is a growing demand for student-centered, transformative digital learning using competency education as an underpinning.

> ***“A growing body of research suggests that overall student achievement is likely to increase when students are able to learn at their own pace with a variety of teaching styles and formats available to them. Personalizing students’ education enables them to access a unique learning experience based upon their individual needs, rather than receiving instruction through a standard, paced curriculum. In its ideal form, the needs of students are put first.”*** [2]

THE PROMISE OF STUDENT-CENTERED LEARNING

The American system of education was built for a society and an economy that no longer exists.[3] The education system still in place in many districts around the country was created in the early 1900s to serve a different time with different needs. This model, often called the factory model system, in essence monolithically processes students in batches. Teachers teach the same subjects to groups of students roughly the same age at the same pace. The system of the one-to-many approach to teaching, as well as age-based cohorts, advancement based on age-grouping or time-based Carnegie credits rather than mastery and classroom-contained instruction, places limits on our children’s opportunities to learn and thrive in this changing world. Students learn at different paces, have different aptitudes and enter classes with different experiences and background knowledge.

Student-centered learning models personalize learning with the use of competency-based approaches, supported by blended and online learning modalities and environments, as well as extended learning options and resources. A focus exists on student ownership of learning. Students share responsibility for their own learning with their teachers, parents/guardians and other support persons. Teachers use technology to analyze and utilize real-time data to differentiate instruction, customize learning and engage students in deeper learning. Students use technology to consider their real-time progress data in focusing their learning, to access resources, to collaborate and communicate with others and to demonstrate evidence of their learning.

Education that is student-centered has tremendous potential, and recent results are promising:

- Decrease in drop-out rates
- Increase in percentage of students accepted into college
- Increase in growth in mathematics—grade level indicators and state assessments
- Increase in growth in reading—grade level indicators and state assessments
- Increase in student engagement
- Decrease in student referrals
- Increase in student agency

Both the Nellie Mae Education Foundation and iNACOL consider the transformation of today's education systems to student-centered learning to be of critical importance.

Nellie Mae Education Foundation Statement on ESSA

"From our perspective at The Nellie Mae Education Foundation, the new law holds great promise for advancing public education, as one of its explicit aims is to grow, spread and improve innovative, evidence-based, student-centered approaches to learning – where learning is personalized, competency-based, dependent on strong student ownership, and not limited to traditional classrooms or classrooms at all. This is good news.

We also believe that there are aspects of this new direction that demand vigilant attention. As we open up opportunities for creativity in terms of educational design, we must make sure that we organize for universal attainment of deeper learning outcomes and do not unintentionally leave more learners behind in the process.

If our nation is going to advance, we must be sure that creative learning designs are effective ones, including in our poorest communities. We must ensure that we are elevating the learning and readiness of graduates of all colors in all zip codes to combat the growing economic inequalities that are so pervasive across our country. While the move to state-owned responsibility and district-based accountability may be the way forward, as advocates of equity, it leaves us uneasy, even as it replaces the untenable approaches to securing equity in NCLB.

ESSA mandates a big shift toward balancing shared responsibility, as the law moves significant decision-making about responses to low performance to the district level guided by state authority. However, the distribution of authority to the local level will demand capacity-building so that local communities can meet those responsibilities. Today most districts do not have the capacity to do so, as so much energy has been directed to a compliance-based framework. This is an issue any advocates of dramatic, equitable change and improvement will care about. It is one thing to open up opportunity. It is another to be able to fully, expertly and responsibly take advantage of the opportunity. Wealthy districts may be able to meet the challenge even if they do not need to, while those who must cannot without support.

On the positive side for student-centered learning advocates, the law includes opportunities for more states to follow the lead of what many in New England have been pursuing for years – personalized, competency-based approaches. It also allows for research supported approaches. This is no accident. One can see echoes of good, innovative work from Rhode Island, Vermont, Maine, Connecticut and particularly New Hampshire in many passages of ESSA. New England should be proud.

While the law maintains many of the requirements for annual testing, it is importantly coupled with greater flexibility to states in the choice and design of those assessments, and how to appropriately hold its public schools accountable. Additionally, the law explicitly provides room for more creative, developmentally appropriate, and meaningful assessment systems by establishing pilot opportunities for innovative, performance-based approaches. Opened initially for up to seven states, and informed by much of what has been learned by education pioneers living and working in the northeast, we believe the six New England states are well positioned to be home to at least one of these initial seven pilot sites. Whether or not our region's contributions will lead to further concentration of federal dollars here or not remains to be seen.

As it moves leverage closer to the ground, ESSA endorses the notion that local democratic processes must be respected. In a region where there are strong experiments around how to focus a future orientation for readiness through direct public dialogue versus a backward attempt at repair through federal mandate, ESSA provides an immediate chance to provoke a broader deliberation around the purposes of education. This means we have a chance to push the pendulum back from viewing public education's main purpose as one of competition among individuals, toward the purpose of readying all our K-12 students for success in post-secondary education so our communities prosper economically, civically and socially.

It is this fundamental public review of the core purposes of public education - along with an embrace of the notion that public education is an essential public good - that will allow this law to be the game changer it needs to be versus the repair job it had to be. If core cultural issues such as these are left unattended, new approaches will only lead to familiar results.

At the Nellie Mae Education Foundation, we look forward to working with many others to make sense of this law, make the most of it and keep an eye on its imperfections so that we can move forward productively and positively toward strong systems of public education characterized by rigorous, equitable student-centered approaches. In this way we can leverage a long overdue policy change to secure a strong future for all New England learners and communities."

-Nick Donohue,
President & CEO, Nellie Mae Education Foundation,
Nellie Mae Education Foundation Statement
on ESSA on December 11, 2015

Section II: Implications of the Four Tenets of Student-Centered Learning for Technology

The importance of student-centered learning for effective education is well established, yet teachers, schools and districts struggle with its implementation. To actually put the tenets of student-centered learning into play requires a whole school and school system transformation supported by a robust, student-centered learning integrated system (SCL IS). Although a wealth of information has been written about student-centered learning and technology, pulling this information together to determine what student-centered learning means for each end user segment and determining the fundamental requirements for the technologies needed to support end users' needs has yet to be comprehensively addressed. A student-centered learning integrated system must support the complicated set of processes that make up personalized, student-owned, collaborative, anytime, anywhere learning and competency-based education. This paper examines these tenets in terms of the primary functional requirements for how technology can be used by students and educators. It looks at the implications of the requirements for parents, advisors, mentors, and school and district leaders, and it proposes functional requirements for these user groups as well. Based on interviews, site visits and research, it emphasizes the importance of analyzing and examining our knowledge of what is currently used and needed and what future developments are needed in an integrated student-centered learning information ecosystem. The conceptual framework discussed in this paper details the design of integrated technology systems to support student-centered learning. The framework integrates the various functions of technology to address the needs of learners, educators, parents/families, administrators and other stakeholders in support of student-centered learning.

The conceptual framework is built on the assumptions of the following design principles of the Nellie Mae Education Foundation for student-centered learning:

» **Learning is Personalized:** Personalized learning recognizes that students engage in different ways and in different places. Students benefit from individually paced, targeted learning tasks that formatively assess existing skills and knowledge and that address the student's needs and interests.

» **Learning is Competency-Based:** Students move ahead when they have demonstrated mastery of content, not when they've reached a certain birthday or undergone the required hours in a classroom.

» **Learning Happens Anytime, Anywhere:** Learning takes place beyond the traditional school day and even the school year. The school's walls are permeable—learning is not restricted to the classroom.

» **Students Take Ownership Over Their Learning:** Student-centered learning engages students in their own success and incorporates their interests and skills into the learning process. Students support one another's progress and celebrate success. (http://studentsatthecenterhub.org/interactive-framework/)

Student-centered learning is different than teacher-centric instruction since it focuses on the individual student and the instructional processes to support a student-centric learning cycle. The core functions and processes that the student-centered learning integrated system must support are learner-centric instead of teacher- or group-centric. In anchoring this system design, one must consider: the individual learner's learning experiences, resources and interactions with peers, educators and others involved in the education; how these experiences and interactions are supported and assessed; and the ways in which these data and reports are used.

ARCHITECTURE DESIGNED TO SUPPORT STUDENT-CENTERED PROCESSES

This conceptual framework is guided by what learning scientists and cognitive science researchers have discovered about how people learn, how people make sense of new concepts and how novices become experts. Many of the discoveries about how the human brain develops have been difficult to apply within traditional teacher and group-centric instructional models. Those same discoveries can and are being applied within technology-enabled models of student-centered learning.

The processes of student-centered learning and the data needed to address student-centered learning are different than the processes and data used to support traditional classroom models, school operations and accountability. Some data essential for school administration, school accountability, legal compliance and answering policy questions are not the just-in-time, individual learner specific type of data used to support the processes at the core of student-centered learning. Instead, data such as the detailed transactions of learner choices and learning experiences, formative feedback and progression within a competency framework prove more valuable in supporting student-centered processes.

The primary design objective of student-centered learning involves optimizing learning for each student. Therefore, one of the most critical functions of the system focuses on enabling personalized learning experiences, which may happen through the learner's direct interaction with a teacher, through a component of the system, with content delivered by the system or as a combination of online and offline experiences. Whether the experience takes place online or offline, the system must facilitate the provision of learning experiences based on individual student strengths, needs, interests and motivations plus meaningful, timely feedback provided by multiple sources in a student-centric interface.

An additional focus of the system design for student-centered learning involves facilitating student ownership of learning by engaging students in co-planning their learning, incorporating their interests and skills into the learning process, monitoring their progression and celebrating their own successes. They gain a clear understanding of what they have mastered, set goals for what they need to know and master long-range, determine what they need to master short-term to reach long-term goals and receive frequent feedback on progress along the way. They use data to diagnose, direct and drive their learning. They find multiple opportunities to direct, reflect and improve on their own learning through formative assessments and data reports that help them understand their own strengths and learning challenges. Students take increasing responsibility for their own learning, using strategies for self-regulation and reflection. Students support one another's progress and celebrate success.

The student-centered learning integrated system needs to support personalized instructional models focusing on meeting each student's needs.

MODULAR ARCHITECTURE

Supporting student-centered learning requires a student-centered learning integrated system that is composed of multiple information systems that work together to enable the desired learning ecosystem. The system must support a complicated set of processes and functionality that make up personalized and competency-based learning, anytime, anywhere learning in multiple settings and during varying periods of time and student ownership. Therefore, this design is modular and based on the integration of multiple technologies. The following core considerations prove essential to a well-designed student-centered learning system:

- » A reference framework for aligning learning experiences, resources, assessment and reporting to the competencies
- » Customized learner profiles that combine data from source systems and input from students, parent, educators and others who work with the student
- » Personalized learning plans that are responsive to the learner as he or she progresses and changes
- » A variety of learning experiences within and beyond the school setting and calendar plus the collection of associated data to inform student progress
- » Access to content, digital resources, human resources and tools through a user-centric interface
- » Meaningful, timely feedback during the learning process
- » Multiple ways of demonstrating and assessing mastery towards competency
- » Relationships, collaboration and communication
- » Dashboards that reveal in real time which concepts and objectives students struggle with, pinpoint at-risk students and enable targeted intervention
- » Analytic tools to support data-informed practices (learning, teaching, administration)
- » Integration of multiple systems and data flows using data and interoperability standards and practices

The software, services and learning content needed to support student-centered learning must be distributed. The integrated system must be flexible and draw on the best-in-the-world resources and technology. In this design, the functions may be provided by different enabling technologies and will require the integration of different teaching, learning and business system applications. Using consistent data standards and establishing interoperability between these applications will enable data to flow more seamlessly. Standards are critical, especially at the points in which separate systems need to integrate and the data from those systems need to interoperate. Numerous data and technical standards exist within the educational space to support interoperability.

What can you take away from this paper?

What a reader might find most useful in this paper will vary by role.

If you are an educator, how will you work with your students and colleagues to optimize student learning, and how can technology promote innovation in a student-centered learning environment?

If you are a leader in the school system, this paper will help you understand how your school system can provide the complex technologies needed to support student-centered learning and enable users to successfully use these technologies. It will also explore how you can take advantage of the data and analytics such systems provide to improve practices.

If you are a technology development leader, you might ask: How can your work fuel student-centered learning? Are you using a student-centered learning integrated system approach with an emphasis on a student-centric view? What can you do to learn from students, educators and community members to engineer systems that meet the needs of the end users? How are you using design principles and data and interoperability standards so that your systems facilitate the openness, extensibility and coherent integration of functionality needed to support the many nuances of student-centered learning? How are you structuring functional requirements in proposal requests with use cases to better identify appropriate IT solutions?

WHAT ARE THE FOUR TENETS OF STUDENT-CENTERED LEARNING?

Let's examine the four tenets of the student-centered learning definition. The following text and graphic draw heavily from the Nellie Mae document, *Putting Students At The Center: A Reference Guide* (http://studentsatthecenterhub.org/wp-content/legacyimg/NMEF_sclrefraмeweb.pdf) and the website, *The Students at the Center Framework* (http://studentsatthecenterhub.org/interactive-framework/).

These four tenets of student-centered learning are based on the mind/brain sciences, learning theory and research on youth development.

1. Learning is Personalized
2. Learning is Competency-based
3. Learning Happens Anytime, Anywhere
4. Students Take Ownership Over Their Learning

These four tenets are essential to students' full engagement in achieving deeper learning outcomes and to enabling all students to achieve what they need to know and master to succeed in college, careers and civic life.

Figure 1. Framework for Student-Centered Education

Learning is Personalized:

Personalized learning recognizes that students engage in learning in different ways and in different places. Students benefit from individually-paced, targeted learning tasks that start from the student's current position, formatively assess skills and knowledge, provide ample, frequent and actionable feedback from multiple sources and address the student's needs and interests. Tasks and learning units might be either individual or collective. Learning is deepened and reinforced through participation in collaborative group work, focused on engaging and increasingly complex and authentic problems and projects, as well as through relationships and community structures in the larger learning environment beyond the classroom itself (e.g., advisory groups, mentoring, internships and community support partnerships).

Learning is Competency-Based:

Students move ahead when they have demonstrated mastery of content, not when they've reached a certain birthday or met the required hours in a classroom. "Competencies are defined by explicit learning objectives that empower students. Students receive timely, differentiated support, and they advance by demonstrating evidence with meaningful assessments via mastery, not seat time."[4] Students have multiple means and opportunities to demonstrate mastery through performance-based and other assessments. Each student is assured of the scaffolding and differentiated support needed to keep progressing at a pace appropriate to reaching college, career and civic outcomes, even when unequal resources are required to achieve a more equitable result.

In 2011, Sturgis and Patrick proposed a five-part working definition of competency education in partnership with the field of K-12 competency-based education leading practitioners at the Competency-based Education Summit hosted by iNACOL and the Council of Chief State School Officers (CCSSO):

» Students advance upon demonstrated mastery.
» Competencies include explicit, measurable, transferable learning objectives that empower students.
» Assessment is meaningful and a positive learning experience for students.
» Students receive rapid, differentiated support based on their individual learning needs.
» Learning outcomes emphasize competencies that include application and creation of knowledge along with the development of important skills and dispositions.[5]

This definition was expanded by the Smarter Balanced Assessment Consortium's Proficiency-Based Learning Task Force, based on the growing body of work around competency education.

» Students advance upon demonstration of mastery of content, 21st-century skills and dispositions that prepare them for college and careers.
» Learning standards are explicit, understood by students and measurable.
» Assessments—formative, interim and summative—measure and promote learning.
» Demonstration of learning uses a variety of assessment methods including in-depth performance assessments that expect application of learning.
» Instruction is personalized, flexible and adaptable to student needs—both initially and as required by student learning.

- Students both direct and lead their learning, even as they learn from and with others—both within and outside of school.
- Grading is used as a form of communication for students, parents and teachers—not control or punishment.[6]

Learning Happens Anytime, Anywhere:
Learning takes place during and beyond the traditional school day—and even the school year. The school's walls are permeable; learning is not restricted to the classroom or the building. Time and place are used flexibly, in ways that optimize and extend student learning and that allow for educators to engage in reflection and planning. Students have equitable opportunities to take advantage of digital technologies that can enhance learning, and they can receive credit for the learning they do outside of school, based on their demonstration of skills and knowledge.

Students Take Ownership Over Their Learning:
Student-centered learning engages students in their own success and incorporates their interests and skills into the learning process. They gain a clear understanding of what they have mastered, set goals for what they need to know and master long-range, determine what they need to master short-term to reach their long-term goals and receive frequent feedback on their progress. They use data to diagnose, direct and drive their learning. They have multiple opportunities to direct, reflect and improve on their own learning through formative assessments and data reports that help them understand their own strengths and learning challenges. Students take increasing responsibility for their own learning, using strategies for self-regulation and reflection. Students support one another's progress and celebrate success.

While implementing any one of these tenets in isolation can be beneficial, the collective embrace and systemic implementation of all the tenets is critical for transforming learning.[7] There is no one-size-fits all strategy to implementing student-centered learning, and both the implementation vision and approach will vary across organizations. Implementation will also vary according to district priorities and resources.

Section III: Design of a Student-Centered Learning Integrated System - Requirements and Use Cases

WHAT THE IMPLICATIONS OF STUDENT-CENTERED LEARNING MEAN FOR TECHNOLOGY

Most existing IT systems in schools were implemented to support a teacher and course-centric approach, as well as compliance reporting for basic student data, course-taking, grades and scheduling data in a time-based system, rather a student-centered, competency-based system for anytime, anywhere learning. This poses particular issues when schools and systems shift to student-centered learning. How should administrators and teachers manage the progress data on learning progressions that includes multiple forms of evidence and levels of mastery for student learning? What systems support learning that takes place beyond the school walls? What is the progress on the student's personalized learning plan? Is there an electronic portfolio and "data backpack" that collects a portfolio of student work and history? What competencies have been accomplished and how? What information are parents and students accessing to empower ownership, voice and choice of robust, personalized learning experiences in a student-centered environment? How is this information collected and shared to support the transition to college and career?

The student-centered learning integrated system must support the complicated set of processes that make up personalized, student-owned, collaborative, anytime, anywhere learning and competency-based education. This requires a different set of "functional requirements" mapped to the different components of a student-centered learning model. It requires breaking down what each end user segment needs to be able to do and identifying how technologies can support that functional need. A gap in the literature exists for the complex subject of functional requirements for student-centered learning. This paper intends to help fill that gap.

USER SCENARIOS

To better understand what student-centered learning would require of an integrated information ecosystem, let's look more closely at some scenarios that describe what students, teachers, parents and educators might want to be able to do as part of their educational system. Then, we will consider the implications for technology.

Student Scenarios

» **Personalized learning, student ownership** - As part of mastering their science and written language standards, Michelle and Rosa decided that they wanted to demonstrate their learning by developing an eBook about butterflies—their roles as pollinators and in the food chain. They took pictures and made observations about butterflies in their community. They collected images and information from the Web, as well as print resources. Working together they problem-solved how to coordinate their efforts, created a plan for getting the eBook completed and used *Book Creator* to add and organize their pictures, type text and add hand-written annotations on the pictures as well as to draw their own pictures. Once the book was created, they added their own oral narrative to further explain things. They also created a food chain diagram that they printed out as a poster for the classroom. Their teacher knew their strengths, needs and interests, because she knew the students well and had access to their learning profiles in the class's online learning environment. She knew that they would need help in finding age-appropriate resources so she created a digital content page in the class's online learning environment with appropriate links and suggested key words. She met with them to help them outline their book, monitored their project plan and supported them as needed throughout the process. They were thrilled with the result of their work and shared their production with others during class and posted it to the class's online learning environment. Each of them included the eBook in their ePortfolio and sent the eBook portfolio link to family and friends. Their teacher used this project as one measure to assess their progress on their content standards and recorded this information in the district's electronic standards tracking system. This information was then automatically updated in the students' learner profiles.

» **Competency-based learning and extended learning options** - Hia has been fascinated by government, politics and programs for young children all of her life. As part of her school program, she is participating in an internship with the local city government office focused on early childhood initiatives. She continues to work with her learning team (herself, her parents, the local government office mentor and her advisor) to identify quarterly goals in her personalized learning plan for this internship; she then sets weekly targets for making and demonstrating progress toward these goals. She has developed a project plan using the school's project-based learning tool. She logs her hours, journals her activities and reflections and collects artifacts to include as evidence of her learning in this same tool. She aligns these articles with the competencies she needs to demonstrate. Her learning team provides feedback on her activities and artifacts directly to Hia, both face-to-face and online, and notes this in her project plan. The learning team can also use the tool to communicate with one another. Hia will develop a showcase portfolio (demonstration) to prove her competence. She does this electronically and will share it with her learning team. As she works on the portfolio, she receives structured feedback by using a rubric that each team member completes over time. She is using this internship to demonstrate growth in her government and Habits of Mind competencies.

» **Anytime, anywhere and community involvement** - Joao is an 18-year-old who missed a year of school due to family health and personal issues. He wanted to graduate within a year but had the equivalent of two years of credits to complete if following a traditional school approach and calendar. He met with his Youth Development Counselor (advisor) to review his personal data dashboard (which includes his Learner Profile), revealing his credit status, progress on competencies and learning targets plus his interests. Together they considered his progress, goals, interests and ways in which he likes to learn and demonstrate learning. He added this information to his Learner Profile. Using this information, they co-developed a personalized learning plan (PLP) that included an extended school day and year, a competency approach to obtaining the required credits and a career-oriented capstone project. As a result, he is taking online and face-to-face courses, some of which are self-paced with teacher monitoring and support, while others are teacher/group-paced due to the project-based learning nature of the tasks. Open Educational Resources are also being used to address specific skills and competencies. These resources include game-based learning, simulations and assessment 'as' learning within an online tutoring system. Using the data dashboard, Joao, his teachers, parents and Youth Development Counselor (YDC) are able to view his progress daily, make comments on the plan and provide feedback or reflections. He can make changes to his PLP to reflect changing needs, motivations and goals as time evolves. One of his teachers noticed that he really liked troubleshooting technology and suggested that he considered working as an intern in a technology group during the summer. His YDC facilitated his obtaining the internship through their youth development partnership network. He will be able to receive credit towards competency completion for this work. The district also has a college/career platform so he can learn about possible career options in this area of interest. Through the district's social learning platform, he can participate in monitored chats with professionals in the field. They can provide real information about potential jobs, a typical workday and different types of technology careers, without knowing his full name, age, school or any other personal information. The college/career platform also tells Joao what courses and extended activities could help him get access to two- or four-year institutions where he can become professionally accredited or receive a diploma in the field. The YDC is working with him to identify potential colleges, sources of funding and scholarship opportunities online. As he learns more, he updates his learner profile. The data from the competency completion is updated by his YDC during his weekly review meetings, based on reports from the teachers and online course platform.

Educator Scenarios

Teachers - Eli is a 4th grader who performs unevenly in school. She is doing well in mathematics but struggling in some areas of reading. English is her second language. Her school system has aligned its digital resources to the state standards. Eli's teachers want to move toward an integrated system that would allow them to:

- See how Eli is doing, review appropriate materials and strategies and assess whether there are any other students in their classes with a similar profile
- Collaborate with Eli's other teachers and support personnel in assigning materials, tasks and assessments aligned at an objective level for the standards Eli needs to master, using a system that recommends appropriate resources and strategies. Use the same interface to view the resources and to assign these materials, tasks and assessments to other students with similar needs. Use the predictive analysis capabilities of the system to project student growth and discuss strategies
- Track daily performance and progress on these tasks and the associated objectives/competencies. The system should accept multiple examples of evidence of learning and data points from the learning environment, allow the teachers to add progress data for tasks and assessments not within the system and update the progress report as new assessment data is added
- Update the progress report as new assessment data is added and revise the competency rating using the district-determined formula
- Integrate the updated progress data into Eli's personalized learning plan to inform instructional planning
- Inform Eli and her parents of the work to be completed, her progress on that work and her current competency attainment on her personalized learning plan[8]

School leader -Principal Orella is concerned about the number of students not doing well on the district and state interim and summative assessments, which have been aligned to the state standards. Principal Orella wants to:

- View how each student is doing by standard, delve into the areas of weakness and view the recommended strategies/materials for these standards
- See a profile of how each student is doing individually and in class groupings for each competency
- Track just-in-time performance and progress based on formative assessment data
- Analyze student demographic data to see if similarities of weaknesses and strengths exist across students
- See each student's progression in attaining the competencies (standards) over multiple years
- Use the predictive analysis capabilities of the system to project student growth

» Determine whether there are any gaps in how standards are covered within curriculum documents, so that curriculum revisions can be targeted, and taught by teachers so mentoring and coaching can be offered as needed
» Use the data to look at student-teacher and content-teacher assignments and scheduling options
» Take advantage of the district information system to set up agile scheduling based on student needs rather than fixed time period designations

District Scenarios

Maryvale School District wants to:

» Analyze student attainment of standards over multiple years. It wants to break this data down by school, teacher, student demographic information, course and individual student, by time period
» Track student achievement history, teacher comments, supports and interventions as well as other indicators, then analyze this data to provide more targeted, effective and equitable student support services
» Evaluate the degree of alignment between instructional resources and standards and examine the relationship between use of instructional resources and student performance
» Assess which resources are being used, when and by whom
» Support flexible scheduling options, such as the assignment of one or more teachers to a course, provide for courses/sessions of variable lengths dependent upon student progression, support "just-in-time" modifications/ additions of courses/session to the schedule based on individual student, as well as group, needs
» Use predictive analytics to do short- and long-term planning of resources needed to support student learning and organizational efficiency

At the core of each of the above scenarios is the focus on the student learning, alignment of competencies/ standards to content, assessments and reporting plus using evidence-based approaches and data regarding the student's progress to inform the student's learning, as well as to inform educator and district practices. Timely, meaningful data and the ability to act upon that data are essential to each of these scenarios. It enables students and educators to make informed judgments about what students have learned, how well they've learned it, what to learn next and effective strategies and resources. In addition, it's crucial to connect students, educators and other supporters to one another and to resources—both material and human.

A number of things differentiate a student-centered instructional cycle from a traditional instructional cycle.

1. The student remains the center of learning, supported by a learning team of partners that include teachers, peers, parents, and others involved in the student's education and well-being.
2. Learning is co-planned by the student and teacher and may involve others in the planning. During the co-planning process, the student, teacher and others involved in the planning process use data, including data in the Student Learning Profile, to review what the student knows and needs to know, as well as what the student wants to learn beyond the required outcomes. The team discusses the resulting personalized goals, competencies, and learning targets, how the student learns best, and the student's interests. It uses this information to determine how the student will demonstrate his/her learning. The locus of control for learning is shared between the student and teachers; and it progressively moves more toward the student as he or she increasingly takes ownership and responsibility for his or her own learning.

3. Learning is based on the individual student's goals plus progress on mastery of clearly defined competencies, needs and strengths, interests and motivations. From this co-planning process, one can develop a personalized learning plan (PLP) that includes goals, competencies, learning targets, instructional approaches and selected ways to demonstrate learning. After developing the PLP, the learning team selects the resources (digital and human) that will be incorporated into the PLP or a playlist-type function.
4. The learning cycle includes ongoing feedback based on multiple measures of student progression toward attaining clearly defined learning targets and competencies.
5. The learning cycle is continuous. If a student does not demonstrate mastery, the learning team analyzes the data and revises the selection and use of instructional approaches, ways to demonstrate learning, selection and assignment of resources (digital and human), feedback strategies and intervals during learning—and perhaps the assessment measures and strategies, too. If a student does demonstrate mastery, the student and teacher may decide that the student will move on or explore the concepts related to the competency in more depth.

The central elements described here form a logical relationship for student learning, as represented in Figure 2 below. This instructional cycle for student-centered learning serves as the foundation for understanding the information systems needed to support that cycle.

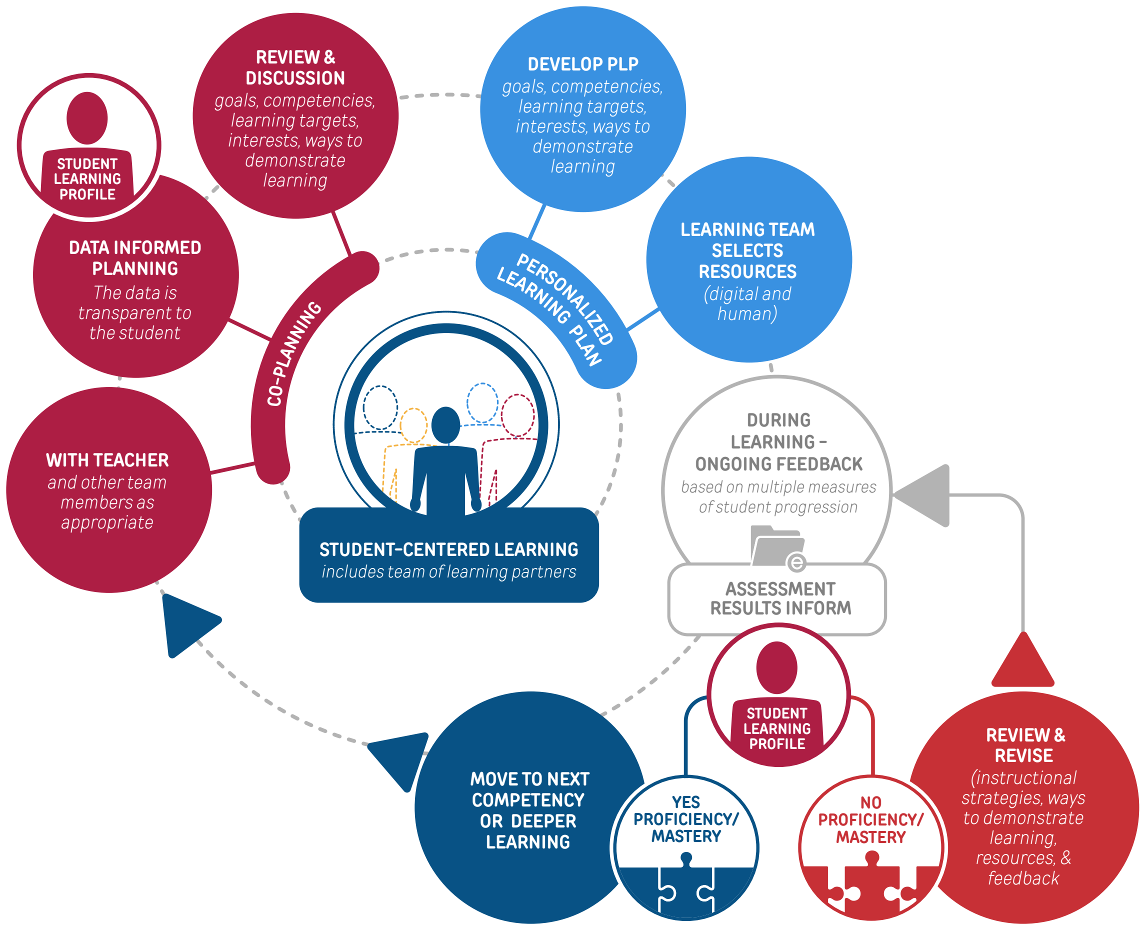


Figure 2. Instructional Cycle for Student-Centered Learning

Is it likely that a single technology platform can support all of the nuanced functions in these scenarios and within this instructional cycle? It is doubtful. Thus, we will explore in detail the implications for what functional capabilities need to be enabled and/or supported by instructional and information systems in student-centered learning models.

IMPLICATIONS FOR TECHNOLOGY TO MEET THE TENETS OF STUDENT-CENTERED LEARNING

The implications for technology in student-centered learning start with examining the user's role and what functional capabilities are implied for this role using by the four tenets of student-centered learning. The information below describes these functional capabilities by end user segment for each of the tenets :

- » Learning is Personalized
- » Learning is Competency-Based
- » Learning Happens Anytime, Anywhere
- » Students Take Ownership Over Their Learning

A school district or governing body for a network of schools might have a variety of approaches to and implementation models for implementing student-centered learning. Districts and schools will need to determine what functional capabilities they want a student-centered learning integrated system to serve based on their vision and implementation models. These implementation models, such as blended learning, competency-based education, project-based/community-based learning, may or may not include all of the implications described here. Schools and school systems will need to determine which of these apply to their current and future practices as they move forward in this work. This is explored in more depth later in this document.

The table below considers some of the primary uses of technology for supporting students and teachers. In the paragraphs following the table, the implications for parents, mentors/internship supervisors, and school and district leaders are considered. Students in this work can be anyone in the learner role, including students, teachers or administrators, but the primary lens utilized here remains on student learners. Teachers can be anyone in the educator's role, including teachers and administrators. In this paper, the primary lens utilized focuses on teachers working with student learners.

LEARNING IS PERSONALIZED	
Student	**Teacher**
Students engage in learning in different ways and in different places	
Students utilize personalized learning plans (PLP) based on student strengths and needs, learning preferences, interests and an understanding of what they need to learn and information on how they learn best. Students co-construct PLPs with teachers and learning coaches. In addition to data imported into the learning plan from the system, teacher or coach, the student can add comments, additional information and learning outcomes. Students can view the feedback on their activities/tasks and comment upon it. Feedback can be in the form of written comments, percentages, proficiency scales, rubrics and/or grades depending upon the program design. Students can electronically log the time spent on learning activities (tasks/artifacts/presentations/projects) and reflect upon their work. The time log and reflections are linked with learning activities, as well as with the associated learning target in their learning plan. The system also tracks time spent, and this data can be made visible to student and teacher.	Teachers can manage student personalized learning plans one at a time and through the use of groups. The system supports the use of filters to enable teachers to group students with like strengths, needs and interests and to create modifications/additions to the individual learning plans of the grouped students simultaneously. Teachers can provide online feedback on the activities/tasks of their students. Feedback can be in the form of written comments, percentages, rubric scales and/or grades depending upon the program design. Teachers should be able to enter attendance and progress information once and to have all systems that need that data populated.
Students have access to reports about how much effort and/or time they have spent on learning targets/competencies and how they are progressing in comparison to their personalized learning plan (this assumes that in the PLP, the student and teachers have agreed to some estimated time parameters around how long attaining a learning target/competency should take. These time parameters can be adjusted as needed). Students can use the predictive analysis capabilities of the system to project their growth if they continue at the same pace or change their pace.	Teachers have access to individual and group reports about how much effort and/or time students have spent on learning targets/competency and how they are progressing in comparison to their personalized learning plan and to other students. The system supports the use of filters to enable teachers to group students with similar strengths, needs and interests and to view progress across the groups. Teachers can use the predictive analysis capabilities of the system to project individual student growth if that student continues at the same pace or changes the pace. In addition to data imported into the learning plan from the system, teachers can add comments and additional information and determine who can see this information.

Students have access to a searchable system of curated open education and commercial learning resources and options aligned with standards and metatagged using a consistent metadata schema. Search and access is enabled through single sign-on and provided at no cost to the student by the school/district. The resources are organized into developmentally appropriate collections. Students can rate items and add notations regarding the items' use. The aligned learning resources incorporate Universal Design for Learning (UDL) principles. Students have 24/7, anywhere access to these resources and course materials, including formative assessments and feedback from computer-scored assessments.	Teachers have access to the same searchable system as the students and can add, hide and organize items within the system. Teachers can assign individual items and collections to individual students or groups of students. Teachers can select metatags from those generated from the system and/or add their own. The software has intelligent algorithms so it can make recommendations for metadata, especially key words and standards alignment for the item. Teachers can edit the metadata of the items that they have submitted and use an electronic workflow process to suggest edits for other items. Teachers can rate items and add notations regarding the items use. Teachers have reports that provide information about the properties of objects within the catalog (repository), including status, publisher, date published, file size, etc. Teachers have reports that provide information about their students' actions performed on resources within the catalog (repository), for example, who viewed or downloaded a resource and when.
Students have the tools to develop artifacts of learning. Students have the means to collect artifacts of learning and metatag them, including alignment with learning targets, standards and competencies, and they can develop them into presentations. When tagging their artifacts, students can select key words and standards from a list of suggested items generated by the software program. Students have the means to demonstrate their learning through presentations that pull from an artifacts collection and additional student-developed material specific to the presentation; rubrics can be associated with the presentation and the student and teacher/others (with permission) can score the rubrics with students being able to view the teacher's/others' scores and their own score. Students have the means to share artifacts, collections and presentations and to receive feedback from teachers as well as student- and teacher-designated others.	Teachers have the same curated technology tools and digital resources and can view artifacts, collections, presentations, metadata and student alignments in order to provide feedback. The teacher/school or district has set up the "tools" with the learning targets, standards and competencies so students can easily associate them with their presentation and artifacts. (Policy and process issue as to who and how this is done.) The software can make recommendations for key words and standards aligned with the content object, and it allows the teacher to select those that apply to add his or her own. Teachers have the tools to view presentations, provide feedback, and enter grade/score into the teaching and learning platform or Student Information System as appropriate (these systems exchange designated grade/score information so only one entry is needed). Rubric/feedback form can be associated with presentation and the teacher can score the rubric with student being able to view the teacher score and student score.

	Teachers have the means to share students' artifacts, collections and presentations and to view feedback provided by others. Teachers can view reports on which students have shared their artifacts, collections and presentations by individual student and by items. This would include who shared, what they shared, with whom and the timeframes.
Individually paced, targeted learning tasks start from where the student is, formatively assess existing and developing skills and knowledge, and they address the student's needs and interests.	
Students are able to view learning maps/reference frameworks with the associated evidence maps (maps that show students different ways to demonstrate mastery of a learning target/standard/competency). Horizontal and vertical views are available. Students have the means to align standards, learning targets and proficiency measures with digital content that they discover or create.	Teachers can develop learning maps/reference frameworks (policy issue with district—who can develop and edit learning maps and reference framework; this permission may be limited to certain roles). Teachers can manage learning maps/reference frameworks. The system supports the use of filters to enable teachers to view maps by competency, standard, learning target and associated proficiency scale, by proficiency scale and by evidence. Teachers can use the maps to develop student personalized learning plans and create modifications/additions to existing plans. Teachers can use the maps to align curricular and assessment resources. The system has an intelligent engine that supports automatic indexing and tagging to learning targets/objectives.
Students are able to view their assessment results at holistic standard/competency and learning target levels.	When a teacher scores an assessment in the system, it transfers that data to the competency tracker. A teacher can view assessment results data in the competency tracker.
Students have an individual student profile that includes system and student/parent/teacher-generated information.	Teachers can add to students' learning profiles. Teachers can view individual profiles, summary data from profiles and delve within the summary data to view which students share similar characteristics.
Students have an individualized data dashboard that displays the integration of data from assessments, interests, competency progressions, learning map/reference framework and personalized learning plans, including recommendations for resources. The personalized learning plan is dynamically updated based on which learning objectives are accomplished and which ones remain to be achieved, using input from performance within the system. The student and teacher/facilitator can input data into the system, and the system can pull integrated data from other sources (i.e., Caliper Analytics, xAPI).	Teachers can view and manage the student dashboards. They can make comments and recommendations, assign individual tasks or provide multiple choices of lessons and activities to specific students or groups of students, provide multiple choices of resources and communicate with specific students or groups of students. They have reports and filters that facilitate the use, management, and viewing of data in the dashboard.

Students are able to generate their own playlists and access playlists developed by their teachers/coaches. The playlists provide indication of whether a student has completed, is in the midst of or has not accessed the item. Playlists allow the easy construction of ordered learning experiences that are linked directly to the items required for that learning experience.	Teachers are able to generate playlists, access playlists developed by others, and assign selected playlists to individuals and/or groups of students. The teacher has reporting capabilities that allow the teacher to view playlists by students to whom they playlist has been assigned and for a playlist by status of completion of each student.
In addition to other learning experiences, students use software programs that incorporate intelligent algorithms/ adaptive software. Selected progress data from these programs can be brought into the dashboard as determined by the teacher or district.	Teachers are able to view software programs that incorporate intelligent algorithms/ adaptive software as a student and as a teacher. Progress data from these programs can be brought into the dashboard. (Policy issue: Determining what data is brought into the analytics engine and displayed in the dashboard and who determines this at what level/role, i.e. teacher, district, specific individual. Tech issue: Can the tech system allow for individual users and/or different roles to determine what data is brought into the analytics engine and displayed in the dashboard.)
LEARNING IS COMPETENCY-BASED	
Students move ahead when they have demonstrated mastery of content.	
Students can provide feedback on their assessment of their level of confidence in their demonstration of learning targets/competencies and provide feedback on the design of the task.	Teachers can view the student self-reports by individual student and by learning target/competency. They can provide feedback to students on student self-reports on their assessment of confidence, compare the student's level of confidence with performance, engage in online and face-to-face dialog with the students and trigger interventions based on the data.
Students have a layered, individualized data dashboard that displays the integration of data from assessments, interests, competency progressions, learning map/ reference framework and personalized learning plans, including recommendations for resources. The dashboard presents a holistic picture and supports drilling down.	Teachers can view and manage the student dashboards. They can make comments and recommendations, assign individual tasks or provide multiple choices of lessons and activities to specific students or groups of students, provide multiple choices of resources, and communicate with specific students or groups of students. They have reports and filters that facilitate the use and management as well as the view of data in the dashboards.

Students have access to a repository of curated digital resources and learning experiences that are designed to enable them to move to the next learning target within a competency, a different learning target or competency and, when a competency is completed, to move to the next competency and/or to enable them to move deeper into a competency area (whether designated by the teacher, the program or student choice).	Teachers can develop resources, add them to the repository, metatag them, share them with others and students, and assign the resources to individual and groups of students. Teachers are able to add additional content repositories to the system. (Policy issue for district: Who can develop and manage content repositories; this permission may be limited to certain roles.) Teachers are able to view and generate reports on the use of the resources (which ones, who used them when, for how long, and how often). Teachers are also able to view reports on the efficacy of the resources, allowing them to take informed actions to improve their materials. Teachers are able to view and generate reports on gaps in content and assessment item alignment and coverage for the learning targets/competencies within topic areas/courses. Teachers can search for and review materials and strategies that would be appropriate for students based on their student profiles.
Students have access to reports about how much effort (or time) they have spent on learning targets/competency and how they are progressing in comparison to their personalized learning plan. (This assumes that, in the PLP, the student and teachers have agreed to some estimated time parameters around how long attaining a learning target/competency should take. These time parameters can be adjusted as needed.)	Teachers have access to reports about how much effort (or time) each student has spent on learning targets/competency and how they are progressing in comparison to their personalized learning plan. (This assumes that, in the PLP, the student and teachers have agreed to some estimated time parameters around how long attaining a learning target/competency should take. These time parameters can be adjusted as needed.) They can also view summary data by learning targets and drill down to see individual student progress for assigned targets.
Students have access to apps that remind them what they need to do in addition to the dashboard. (Apps send the information as alerts/messages, whereas the dashboard is accessed by the student.) They can set parameters for these apps, as well as have them set by the teacher. They cannot override parameters set by the teacher.	Teachers have access to apps that remind them what they need to do in addition to the dashboard. They can set parameters for these apps, as well as have them set by the school leader. They cannot override parameters set by the school leader. They can set the parameters for students enrolled in their classes.

See Learning is Personalized for portfolio/project-based learning type tasks.

LEARNING HAPPENS ANYTIME, ANYWHERE

Learning takes place beyond the traditional school day—and even the school year. The school's walls are permeable; learning is not restricted to the classroom or the building.

Students use systems that support blended, online, face-to-face and extended experiences guided by their personalized learning plan.	Teachers use systems that support blended, online, face-to-face and extended experiences personalized for their students.
Students have 24/7 access to a catalog and wide variety of learning resources and options aligned with standards and interests (see above).	Teachers use online resources and courses to support student learning aligned with standards, student needs and interests. Teachers can assign these resources to individuals and/or groups of students.
Students work with mentors, experts and advisors face-to-face and virtually through the use of technology. They can communicate privately one-to-one or one-to-many (examples: email, discussions, chats, texts, webinars, portfolios and public messaging).	Teachers work with their students' mentors, experts and advisors face-to-face and virtually through the use of technology. They can communicate privately one-to-one or one-to-many. Teachers and mentors can log time they have spent with a student on a task/internship, reflect upon the work their students have done, share this with their students, and review and comment upon the student's reflections. Teachers have access to and can generate reports on the number of contacts between students and mentors. They can review, add and edit the learning targets that are in the PLP. They can view reflections organized by student, mentor, and learning targets.
Students collaborate with site mentors to establish learning targets that are included in and reported upon in the PLP.	
Students can electronically log their time spent on a task/internship, reflect upon their work and share this with their mentors/advisors.	
Students are able to submit demonstrations of knowledge and skills obtained beyond the traditional school day and year, and have this work contribute toward their competency progression. The student and those who support the student's learning can align demonstrations with learning targets, standards or competencies. Students can select from teacher-designed proficiency scales and rubrics that can be used to assess student demonstrations. They can copy and then edit existing rubrics or design their own with teacher input and approval.	Teachers can design and share proficiency scales and rubrics that can be used to assess student demonstrations, use existing scales and rubric, and/or edit existing proficiency scales and rubrics. Demonstrations can be evaluated according to multiple learning targets and standards/competencies.
Students are able to submit work, to read teacher feedback and comments, and to see rubric feedback and associated grades/progress indicators online.	Teachers are able to view and comment on submitted work, provide feedback, provide rubric feedback and access associated grades/progress indicators online.

Students are able to take online assessments that provide timely, informative feedback in secure online assessment-taking conditions. Assessments embedded within online learning activities also provide feedback and contribute to the evidence of learning.	Teachers have access to robust assessment development tools that allow them to add item response, question and assessment level hints and feedback. They are able to design online resources and assessments that provide informative feedback. Teachers can align whole assessments, sections of assessments and assessment questions/components to standards and review assessment reports that include standard mastery results. Teachers can view whether students read the hint or feedback.
Students participate in formal and informal learning with mechanisms in place to collect performance data (example: xAPI, journaling/blogs, portfolios, Caliper Analytics).	Teachers can view reports on student performance that includes this data, then apply this knowledge to planning.
Students have access to and use district-designated tools that support social learning.	Teachers are able to monitor student usage of the district-designated tools that support social learning. They can message students to edit or remove postings/content and can edit or remove postings/content if needed.
Students have access to a single sign-on portal where they can gain access to their dashboard, PLP, software and applications, assignments, etc.	Teachers have access to a single sign-on portal where they can gain access to their and their students' dashboards, PLPs, software and applications, assignments, etc.
Students have access to devices that may include mobile devices. The technology is device agnostic (laptop, smartphone, tablet) and supports UDL principles.	Teachers know how to support student usage of the devices.
Assistive devices are available as needed, and the integrated learning system components needed by students function with the devices.	Assistive devices are available as needed, and the integrated learning system components needed by teachers function with the devices.
STUDENTS TAKE OWNERSHIP OVER THEIR LEARNING	
Student-centered learning engages students in their own success—and incorporates their interests and skills into the learning process.	
Students use information and tools to help them research career and college opportunities that match their individual talents and interests and to identify their personal career and college goals, revising these over time.	Teachers are able to add information to the tools. They have access to reports that show the student goals by student, by career and by educational requirements.
Students use information and tools to determine the educational requirements for reaching those goals and to help guide them in making the appropriate decisions for course-taking and extracurricular activities.	

Students know what they are expected to know and do and the criteria by which proficiency will be assessed. This information exists in the district learning maps and in student-specific learning plans based on performance data. Students have a strong understanding of what proficiency looks like—proficiency scales, rubrics and examples of student work can be easily referenced.	Teachers have access to tools that support the development and sharing of learning targets, competencies, proficiency scales and rubrics. They can use these tools to access district-developed learning maps and to develop and share their own learning maps (policy issue). Teachers have access to tools that support the development and sharing of learning targets and student personalized learning plans.
Students participate in and design their own projects/learning experiences and align them with standards in collaboration with a teacher or learning coach. Projects/experiences include assessment strategies that support students demonstrating deeper learning and progress on competencies/standards. Students can select from teacher-designed proficiency scales, rubrics, and forms that can be used to assess student projects/learning experiences, copy and then edit these or design their own with teacher input and approval.	Teachers have tools that help them manage the workflow associated with student projects/learning experiences. They can design their own and assign them to students, becoming co-collaborators with students in designing and approving student-initiated projects. Teachers can design and share proficiency scales and rubrics that can be used to assess student demonstrations, use existing scales and rubric, and/or edit existing proficiency scales and rubrics. Demonstrations can be evaluated according to multiple learning targets and standards/competencies.
Students can review and comment upon the feedback provided to them on assessments (formative and summative). The technology tracks the date and time that the student reads the feedback.	Teachers can view reports on whether students have read the feedback and can receive notifications if students have not read the feedback. They can use the tool to trigger notices to themselves and students about reading feedback, and they can also add additional feedback.
Students use the data dashboard — integration of data from assessments, interests, and ePortfolio — to help them with planning and decision-making.	Teachers can add to/edit the individual student data dashboards.
Students can review reports estimating their proficiency on a competency based on data accumulated over time and multiple measures.	Teachers can review reports estimating student’s proficiency on a competency, based on data accumulated over time through multiple measures by individual student, by group or class, by competency and by students within a time period.
Students can reflect electronically on their learning—how they have progressed (what they learned or continue to struggle with) and whether they would they use the same strategy/materials or change and how (forms, survey, portfolio), plus how they can apply what they have learned.	Teachers are able to design forms to help support reflection. They are able to view and develop reports by student, by group, by strategy, and by material and content with which students have struggled.
Students are able to provide feedback electronically on their perception of the quality of content and lessons, the classroom and school environment.	Teachers are able to read the feedback by student, by content, by object, by quality ratings/indicators.

Students have a PLP that is co-developed with a teacher/learning coach based on student strengths and needs, learning preferences, interests and an understanding of what they need to learn and information on how they learn best. Students can update this plan based on progress data and changes in personal interests and needs.	Teachers can contribute to a student's PLP individually and by group. Teachers can review reports on the contents of the PLPs by individual student, by group or class, by competency, by students within a time period, by demonstration method and by resources assigned.
Students are able to use technology to help communicate to others their interests, needs, goals and progress. Students use their PLPs and data dashboard, as well as portfolio, to lead conferences in which they present their progress and evidence of progress.	
Students can contribute information to their learner profile.	Teachers can contribute to student profiles and edit a profile if needed.
Students use technology to help with time management such as calendar scheduling, to-do items and task analysis.	Teachers are able to add items to students' individual and group calendars and to set up to-do lists that students can manage. They can see reports on who has accomplished or not accomplished assigned tasks.
Students use their data dashboard and alerts to help them identify when they need extra support, and they use the system to seek such support. Proactive messaging and alerting capabilities help students identify issues that require the student's or teacher's attention.	Teachers have access to aggregated data so they can group students for support and interventions. Proactive messaging and alerting capabilities help teachers identify issues requiring their own or administrative attention.
Students support each other's progress and celebrate success.	
Students are able to use project management tools to assign responsibility (letting project members know what work they need to get done), to set project timelines and benchmarks, to document progress and to communicate with project members.	Teachers are able to use project management tools to assign responsibility (letting project members know what work they need to get done), to set project timelines and benchmarks, to document progress and to communicate with project members. Teachers are able to monitor students' progress on tasks related to the project and the students' use of the project management tool.
Students participate in online synchronous and asynchronous communication with peers and others.	Teachers can participate in online synchronous and asynchronous communication with students, peers and others. Teachers have access to reports about communication activities by students. Teachers are able to set/receive notifications about student-to-student online chats and notifications about students requesting feedback or messages from students that require responses.

Students use collaboration tools to co-produce work products.	Teachers use collaboration tools to co-develop work products, to view and comment on student products.
Students receive awards and can award themselves and others using badges or other symbols of progress.	Teachers receive awards and can award others using badges or other symbols of progress. Teachers can set up the parameters of the badges.
Students participate in Self-Review/Peer Review/Teacher Review Cycle using online rubrics (proficiency scales). Students can complete rubrics on their own work and use rubrics to provide feedback on peers' work.	Teachers can provide feedback using rubrics, view students' ratings of themselves and view rubric ratings completed by others involved with the student and others. Teachers have reports on individual student ratings on rubrics, plus group and class ratings over time.

The lists below consider the implications for some of the other roles involved in supporting student learning. Not all roles in an educational setting are included, but the major roles of parents/guardians, advisors, mentors/internship supervisors, and school and district leaders are present.

Parent/Guardian

» Can view student work and feedback on the work
» Has access to summary data on their child's (children's) progress and can drill down into progress reports by standard and tasks
» Can access online, aligned, vetted resources provided by the school and district to support the student in advancing toward mastery
» Can view, add to and restrict access to information in the student's learner profile in collaboration with the school district to address privacy concerns
» Can receive alerts regarding student progress, assignments and calendar items
» Can use district communication tools to collaborate with teachers and school staff

Advisors

» Can collaborate online with student to establish goals aligned with competencies, tasks, milestones and evidence of progress indicators
» Can contribute to the advisees' profiles and learning plans
» Can help document student activity/attendance in out-of-school and virtual learning
» Can view student work and provide feedback on the work
» Has access to summary data on their advisees' progress and can drill down into progress reports by standard and tasks
» Can access online, aligned, vetted resources provided by the school and district to advise/support the student in advancing toward mastery
» Can use district communication tools to collaborate with their advisees and teachers, parents, school staff and others involved in the advisees' education

Mentor/Internship Supervisor

- Can collaborate online with student to establish goals aligned with competencies, tasks, milestones and evidence of progress indicators
- Can develop, administer and score assessments related to the work that the student is doing with them
- Can receive feedback from student, teachers and school staff
- Can view student work and provide feedback on the work that the student is doing with them
- Has access to summary data on their student's progress on the work related directly to their area of responsibility and can drill down into progress reports by standard and tasks
- Can access online, aligned, vetted resources provided by the school and district to support the student in advancing toward mastery
- Can use district's communication tools to collaborate with their student's teachers and school staff

School Leadership

Principals and program leaders have access to a wealth of targeted data and reports to help make instruction, curricular and administrative decisions.

- Can view aggregated and individual student growth data by teacher, demographic and other data groups and building level, with a capability to identify trends and gaps; can utilize canned and district-designed custom reports and run ad-hoc reports
- Can view learner profile reporting by individual student, groups, teacher and school
- Can view data dashboard which includes progress on the competencies, learning objectives, and the assessment tasks and rubrics associated with the objectives—in real time and longitudinally. Can view data by individual student, groups, teacher and school in real time and longitudinally. Can use the predictive analysis capabilities of the system to project individual student growth if that student continues at same pace or changes the pace
- Can receive notifications from the system that alerts the user of data that should be looked at, based on pre-determined and customized algorithms. Allows leaders to view analysis of effective strategies and resources by competency attainment
- Ability to allow the review of digital content usage and analytics so leaders can determine whether there were any standards alignment gaps in the curriculum or in how teachers assign resources to support student progress
- Scheduling capabilities needed to support scheduling flexibility, such as
    - Cohort, teacher-paced model—Classes are designed for cohorts of students who are working on the same competencies within a content strain and run for pre-determined lengths of time, such as twelve weeks. The scheduling system needs the ability to assign students to a class and then move those students who have mastered the competencies to the next class. If a student has not mastered the competencies but can complete the un-mastered competencies in a short term "class session" and quickly catch up to pace in the new class, the student can be assigned to the short-term session and the new class simultaneously or sequentially. If the student cannot master the un-mastered competencies within the timeframe of a short term "class session," the student is assigned to an

alternative approach, such as a lab or internship for the duration of length of the next class.
  - Cohort, student and teacher-paced model—Daily/weekly schedule of teacher-led activities. Teachers would be able to let everyone know who is teaching what and when, for example seminars or reviews at certain times. This knowledge of the schedule of teacher-led activities would allow students (in collaboration with teachers) to construct their own day in order to meet individualized goals.
  - Student progress-paced—Ability to assign students to content, groups and classes based on what students need to learn, what they have mastered, and student interests. There are no set lengths of time for these assignments since they are based on student-progress and interests.
  - Traditional school calendars and grade levels—Provide data reports on student needs and progress that can help inform the development of master schedule.
- » System will recognize whether students are missing opportunities for needed support and/or enhancement
- » System will support reporting that help inform what PD needs exist for training, support for teachers

District Leadership

District leaders will need to have access to a wealth of data and reports to help make instruction, curricular and administrative decisions. The data requirements of student-centered learning necessitate a well-designed data governance strategy to be in place. Often an abundance of data exists, so addressing the questions of what data for what purpose, what audience, and in what format and frequency becomes essential. The SCL IS should:

- » Support single sign-on for users to all applications
- » Support seamless integration of multiple systems through the support and use of interoperability and data standards
- » Support the integration of data from multiple sources including community organizations that are working with the school system and city services data
- » Enable the development and delivery of a variety of reports based on end user needs
- » Support the development and hosting of a reference framework that serves as the backbone for the learning maps and assessment mapping; ability to use the content from the reference framework in related applications without having to manually re-enter the information (for example, drag and drop, pull-down)
- » Support the development and management of competencies, standards, and learning targets in an integrated database with a unique identifier and version control. Support the use of templates for the development of competencies
- » Enable the alignment of curriculum, resources and assessments to competency standards and client-driven taxonomies
- » Track a student's just-in-time and longitudinal progress from wherever the student is learning
- » Support comprehensive, balanced assessment ecosystems that enable multiple measures of learning over extended time periods, entry-level assessments to help identify gaps and accurately pinpoint what level a student is entering in their zone of proximal-development, and district and school-level formative assessments to inform and guide daily instruction, as well as provide for summative assessments. Assessments of learning can be individually administered when the student has mastered the content needed for the assessment. The system can support rolling up the data from multiple assessments to report on attainment of competency mastery.

- Support collaborative development of proficiency rubrics for assessing students equitably
- Support setting district mastery criteria for competency attainment
- Support digital resource management
- Support differentiated learning paths for each competency through the creation of unique instructional pathways aligned to competency mastery and student needs, strengths and interests
- Support the transmission of competency evaluation data from the learning environment to the SIS or system of record, so results can be reported on a CBE-based report card and transcript
- Enable sharing teachers, courses and resources within and across schools and across school year calendars
- Provide a platform for teams of teachers within and across schools to work collaboratively
- Provide access to a dashboard that includes performance data for every student, school and program in real time and longitudinally
- Enable tracking of student achievement history, teacher comments, supports and interventions plus other indicators
- Provide the ability to purchase and manage licenses for digital resources and assignment of those resources to different levels of users, schools, classes, teachers and students
- Import roster data to set up classes in the learning environment from the district's core information systems, such as HR and SIS
- Support the assignment of one or more teachers to a student
- Provide an analytics system that includes canned reports, district custom reports and a robust ad hoc reporting capability
- Provide analytics that allow district leadership to view standards alignment gaps in the curriculum and digital resources and that supports the analyses of effective strategies and resources, for example: What resources are having the greatest impact, little to no impact and how are they being used; what is the cost of the resource?
- Support analytics that will allow the district to conduct evaluation activities assessing questions such as, "Is this approach working for us? How do we know how well it is working and for whom?"
- Provide an analytics system that enables predictive analytics, so the district deploy is able to do short- and long-term planning of resources needed to support student learning and organizational efficiency
- Meet guidelines for data security and student privacy
- Support periodic auditing of the system to ensure equity

Users of a student-centered learning integrated system will have different needs dependent upon the user's role and the model(s) of student-centered learning being implemented. These needs should be the basis for the design and selection of technology systems within the integrated system.

For a Student, a student-centered learning integrated system (SCL IS) would include a learner profile that the learner, teacher and parent can adjust over time and a co-developed, personalized learning plan that details learning goals, competencies, learning targets, instructional strategies and selected ways to demonstrate learning. The SCL IS would support students being able to participate in the evaluation of their learning, determine what evidence of learning they want to include in the evaluation, contribute to the design of their assessments and include reflections on learning, thus enabling students to take more responsibility for demonstrating progress. It would also provide access to appropriate material and human resources in order to support advancement toward mastery. Enabling technologies would support digital content, online learning, assessments and portfolio development. Students should have the ability to contribute to their learner profile and data dashboard. The dashboards should be customizable by the user and should contain mobile views. Some data may be required for constant viewing, with the district/school/teacher making those decisions. Students should be able to have some level of ownership over what to monitor and what alerts to trigger.

For a parent, guardian, or mentor, a student-centered learning integrated system would include access to meaningful reports on his or her child's performance including competency progression (what has been mastered and which competencies are yet to be mastered), grades (if used), rubric ratings on tasks, student self-assessment, and teachers' comments. A parent should be able access appropriately vetted resources aligned with the competencies/standards to support his or her child in advancing upon mastery and to be able to use district or personal communication tools to collaborate with the child's (children's) teachers and school staff. Parents should have the ability to contribute to their child's learner profile.

For a teacher, a student-centered learning integrated system would provide a dashboard that includes access to learner profiles, personalized learning plans, and competency and other relevant performance data for his or her students. From this dashboard, the teacher could enter performance data and search for and review materials and strategies that would be appropriate for students based on their profiles and personalized learning plans. The teacher can then assign these materials, tasks and assessments to students and groups of students, update learner profiles and personalized learning plans, as well as monitor daily performance and progress on these tasks, in addition to the associated objectives/competencies. The SCL IS would support the use of customized alerts for teachers, students and parents.

Enabling technologies would support online instruction, assessments, collaboration, project-based learning management and data collection. Teachers would be able to develop and contribute to the collection of aligned resources and use district-, teacher- or student-designed proficiency scales and rubrics to assess student demonstrations of learning. Teachers would be able to view and comment on submitted work, provide feedback in multiple formats and locations, provide rubric feedback and enter data associated grades/progress indicators online. The SCL IS should support data exchanges between the component systems, meaning data is entered once and then can be exchanged with the appropriate integrated systems.

Since this new paradigm involves learning teams and collaboration, the SCL IS will need to support the concepts of many (the learning team) to one (student), flexible scheduling and online collaboration.

For a school or district leader, a student-centered learning integrated system would provide a dashboard that includes access to learner profiles, personalized learning plans, competency and other relevant performance data for every student, as well as access to aligned resources and assessments. The SCL IS would also enable the district to implement its workflow and quality assurance processes for the system components that provide the aligned resources to support teaching and learning.

The SCL IS would support reporting on individual student progress, group progress, class progress, and school and district progress, in real time and longitudinally. Progress views would include progress on the competencies, associated learning objectives, and the assessment tasks and rubrics associated with the objectives. Additional analytics would allow the leader to view whether any competency alignment gaps exist in the curriculum or in the ways in which teachers assign resources to support student competency attainment, assess which resources are being used, when and by whom and examine the relationship between use of instructional resources and student performance. It would help them discern when a student, teacher or school may need additional resources or targeted assistance—or when a student, teacher or school is making exceptional progress so these practices within the classroom and school could be studied and shared. The inclusion of alerts/notifications and flags could assist this process of identification. The ability to view information on what strategies and resources were associated with the student(s) from links within the alerts/notifications would greatly assist in planning.

The student-centered learning integrated system would support data exchanges between the component systems, so data is entered once and then can be exchanged with the appropriate integrated systems. It would support the conversion and transfer of data to state reporting systems. The SCL IS would include a comprehensive data system consisting of learning management systems, observation/measurement systems, evidence of learning systems, and social and collaborative learning systems offering appropriate integration with the system of record and reporting. "These systems should be able to track student achievement history, teacher comments, supports and interventions and other indicators while protecting student-level privacy."[9] Using the data from the system, the district should be able to deploy predictive analytics for better short- and long-term planning of resources needed to support student learning.

At the center of all of these descriptions sits the focus on optimizing student learning through a variety of personalized tools, resources, strategies, collaboration and the use of robust data reporting and technology.

EFFICIENCIES AND QUESTIONS OF PRACTICE

The district has a major role in supporting some of the "backend" work that will make the integrated system more efficient for students and teachers. Pre-loading competency taxonomies, proficiency scales and their associated rubrics, learning maps, a set of curated digital resources aligned with the competencies and metatagged with a district-defined set of metadata elements and formative assessment items aligned with the learning targets/competencies will greatly reduce the time demands on the system users. Processes that include developing or curating these in collaboration with students and teachers will increase their quality and likelihood of adoption. Tasks such as privacy, intellectual property, quality standards for content and metadata plus procedures for who can add resources and workflow need to be developed with a consistent approach across the school system and applied within the system.

Section IV: Shifting from Traditional Course-Based Information Systems to Student-Centered Learning Integrated Systems

This section discusses the need to move from traditional course/teacher-centric systems to student-centric systems, and it presents a conceptual architecture for the overall business capabilities and enabling technologies needed at the district level to support student-centered learning. This is more of an enterprise level approach. Following this section, a detailed, student-centric view of the IT ecosystem for supporting student-centered learning will be discussed.

THE SHIFT FROM TRADITIONAL COURSE-BASED INFORMATION SYSTEMS TO STUDENT-CENTERED LEARNING INTEGRATED SYSTEMS

Changes in how students learn from the traditional teacher- and course-centric approach to a student-centric approach must be reflected in how, when and where students learn, how they plan their learning and demonstrate mastery, how their progress is tracked and reported, how they access resources and the nature of the resources, how they communicate and collaborate with others as well as how teacher, parents and other educators work with and support students. The processes of student-centered learning and the data that prove most critical to support student-centered learning are different from the processes and data used to support traditional classroom models and school operations. Many of the current information and data systems were designed with a course-centric/teacher-centric approach needed for basic accountability compliance and to support a "factory model" of school organization, including school accountability, legal compliance, scheduling and resource allocation. Many of the data systems hold demographic data, student counts, attendance, grades, achievement levels, assessment results and credits organized in course-based and/or grade-level and time-based structures.

These traditional systems are actually "data poor" and functionally limited environments for supporting the learning cycle at the heart of student-centered learning and for using this information to inform instructional and organizational practices. "The traditional model of education, and

> ***"Legacy systems designed for one approach to learning are ill-suited for the types of learning interactions that characterize many of today's student-centered learning practices. Learning management systems designed to support instructor-led subject and grade-delineated courses do not easily lend themselves to competency-based progression. Student information systems designed to support a single learning environment are poorly equipped for managing student's accruing learning experiences in a variety of academic and non-traditional settings."*** [10]
>
> *Parthenon*

our current IT systems, assumes that students follow a linear progression to high school graduation. However, the more we learn about learning, the more we understand that learning is multidimensional. Students may vary in how they progress across the different academic disciplines. Their pace may slow down as they dive deep into a topic or need to spend more time to understand."[11] Students will require differing kinds of resources and levels of time and support for mastering new or missing knowledge and skills in order to move forward on an accelerated learning path. The IT systems need to hold the data for each student that reflects attainment of mastery in relation to the standards over time and location. The effective collection of, analysis of and responsiveness to student data are central to the development of student-centered learning environments. These changes in defining student progress impact accountability measures and the information systems needed to support accountability reporting.

While considering a student-centered learning integrated system, it is important to keep student learning at the center, to incorporate data standards and interoperability principles and to leverage an enterprise architecture approach that enables schools and districts to effectively manage their organizations. The student instructional cycle and use of data are the core focus of a more encompassing systems approach that includes changing the core business capabilities and roles of everyone involved in the educational process. There are significant impacts on the information systems and the business capabilities a district or school deploys in supporting student-centered learning. Core business capabilities are considered the school district's distinct and differentiated business capabilities that are independent of the organization's structure, systems, processes, people or domains.

A structured approach to this transformation that uses the methods and practices of process improvement and redesign is a helpful practice in analyzing and defining the business capabilities needed. A description of this process and work exists beyond the scope of this paper. However, the idealized conceptual architecture below is based on work in this field.

To support the implementation of student-centered learning, an idealized conceptual architecture would include processes and systems to support these core functional capabilities that support the district business capabilities :

» Student Profile
» Learning Management
» Online Learning Environment
» Assessment Management
» Learning Materials Management
» Curriculum Management
» Social Learning and Collaboration
» Evidence of Learning
» Intervention and Support
» Performance Management
» Reporting and Analytics
» Learning Resources Management

Figure 3. Conceptual Architecture: District Core Capabilities for Student-Centered Learning

Standards Reference Framework

The Standards Reference Framework, used by many of the other core functions, is comprised of the specific competencies and learning targets that have been designed by state, district or schools. The reference framework defines what a learner should know or be able to do, and it defines rules for measures that indicate levels of mastery. The reference framework may include additional information about how to measure levels of mastery, more granular competencies (such as process steps that make up a skill) and relationships between individual competencies (e.g., prerequisite/post-requisite relationships).

Student Profile

The purpose of this capability is to integrate all relevant points of information related to students into comprehensive portraits of each student, including his or her achievement data, strengths, needs, interests, ways he or she learns best and preferences, while making this profile accessible to users and stakeholders. This information covers data such as demographic information, state testing data, attendance, supplementary student supports, performance data on competency progression, interests and motivations, credits and course completions, assessment of evidence of learning tied to portfolios and performance/project-based learning, specific misconceptions, habitual mistakes or exemplary practices that apply across learning objectives, such as self-agency skills and teacher, parent, advisory observations and student self-reports. These data points currently exist in numerous pockets, such as student assessment data in a Student Information System (SIS), competency progress records in a competency reporting system, user profiles in a learning management system (LMS) or a transcript in a records-keeping system. Rarely are all pieces of information on the student's history, progress and learning pathway available in the same place. The student profile function integrates a full set of available data on the student and makes it available to other information systems.

The Online Learning Environment (Personal Workspace) would provide the interface for the aggregated data across the architecture and present it seamlessly in a dashboard, along with the student personalized learning plan.

Learning Management

Learning Management ties together the components of curriculum, instruction, communication, assessments, e-Portfolios, student information and other features to manage and facilitate student-centered learning.

Online Learning Environment (Personal Workspace)

The Online Learning Environment supports the integration of and user access to an intuitive interface for the users (students, teachers, administrators) to view and manage their student profiles, personalized learning plans, data, content, lesson plans, accomplishments, etc. It supports an aggregated view of all relevant information to provide a holistic view of each student's personalized learning plan and progress, often in the form of a dashboard. It provides the context from which the learning experience is delivered, and students take ownership of their learning by tying together the various functional capabilities and sources of information that enable the student-centered learning model. From the learner's point of view, all of the online feedback and guidance directing their personalized learning plan is "in" the workspace, but in reality, there may be separate systems supplying the learning maps, alerts, recommendations, social learning and collaboration and feedback to scaffold the transition between discrete learning experiences.

Observation/Measurement Management

Observation/Measurement includes the ability to:

- Develop items and assessments and align them with learning targets and competencies
- Provide an item bank for formative assessments
- Develop and house rubric definitions to link the results of an assessment to the criterion levels within a rubric
- Collect and maintain learning experience data
- Plan and execute the administering of assessments online
- Record assessment results from offline assessments
- Provide that information where needed, such as to enable personalized learning
- In competency education, Observation/Measurement Management systems support the ability to record progress on competency assessments with a longitudinal perspective in which students can be reassessed on a competency
- Assessment Management also supports the ability to tie assessment data to the learning plan and the curriculum to enable student-centered learning

Learning Material Management

Learning Material Management enables the processes around gathering applicable content (i.e. curriculum, vendor content, library resources, etc.) and making it available to those who need it. It is akin to the processes supported by a content management system, but it enables the requirements specific to K–12 educational content. This also includes the function of interfacing with financial or procurement systems, as necessary, to acquire external content.

Curriculum Management

Curriculum Management encompasses the administrative processes and procedures involved in maintaining accurate, up-to-date information about the curriculum a school district offers. Curriculum Management enables curriculum developers and other administrators to build, refine and modify the specifics of a given curriculum in order to share it with stakeholders or other systems. Curriculum Management has a strong relationship to all other core competency education capabilities, particularly the Reference Framework, Learning Material and Resource Management, in its sharing and storing of learning resources.

Evidence of Learning

Evidence of Learning supports achievement tracking of milestones reached by the student with links to the evidence of that learning. Competency-based achievements link back to competencies defined in the Reference Framework and are based on evidence from observations and measurements. Achievement tracking also supports pulling in verifiable electronic records of a person's achievements or qualifications from organizations outside of the school setting in order to get a complete picture of learner competencies. It also provides the portfolio functionality of being able to store artifacts of learning and link the evaluation of those artifacts to a rubric score.

Social and Collaborative Learning and Collaboration

The purpose of this capability is to enable and support social and collaborative learning (learning from and working with others). Social and collaborative learning activities can include collaborative writing and creating, group projects, synchronous and asynchronous discussions, joint problem solving of authentic issues or challenges, social bookmarking and networking and other activities.

Intervention and Support

The purpose of this capability is to enable students to receive timely, differentiated support based on their individual learning needs. It integrates the functions of progress monitoring by educators, academic advisory, scheduling, career/college guidance, links to health, youth and family services, motivational profiles, recommendation engines and dynamic scheduling. A continuous improvement system is in place that helps keep students within or above pacing expectations

Performance Management

Performance Management in this context focuses on optimizing organizational performance and promoting individual growth and development within the competency education framework. Performance Management includes the analysis of data on student progress and the use of resources to support teachers, principals and the district in improving performance. Teachers use the analysis to reflect and adjust their own practice, structure collaboration with other teachers and drive their professional development. Principals and teachers use the analysis to adjust schedules, deploy resources and provide support to teachers. Districts use the analysis to optimize resource allocations.

Reporting and Analytics

Reporting and Analytics support the student-centered learning model by capturing a broad range of student learning and tracking student progress towards mastery, creating the design and implementation of a variety of data dashboards based on stakeholder needs and preferences, providing other indicators to inform teachers of individual or group progress and to design and implement a comprehensive accountability structure focused on learner growth and achievement, which uses multiple measures of learner proficiency tracked over time. Such a system should also identify underperforming schools and track deployment and effectiveness of targeted assistance and support.

Learning Resource Management

This capability relates to the idea of tracking which resources get used, when and how and, when tied to assessment and evaluation data, which resources are effective. This requires heavy reliance on assessment and curriculum data, but it is a powerful tool to enable data-driven instruction.

A student-centered learning integrated system needs to be organized around students' learning experiences and the performance data regarding these experiences, personalized learning plans, competency attainment, multiple pathways, systems of assessments and student ownership. In addition, the systems must support the multiple functions and responsibilities of the education system in supporting student growth, organization effectiveness and efficiencies and accountability.

To support the core business capabilities, a district needs enabling IT applications, as represented in Figure 4. These applications are the types of technologies that support the core functions of a student-centered learning integrated system.

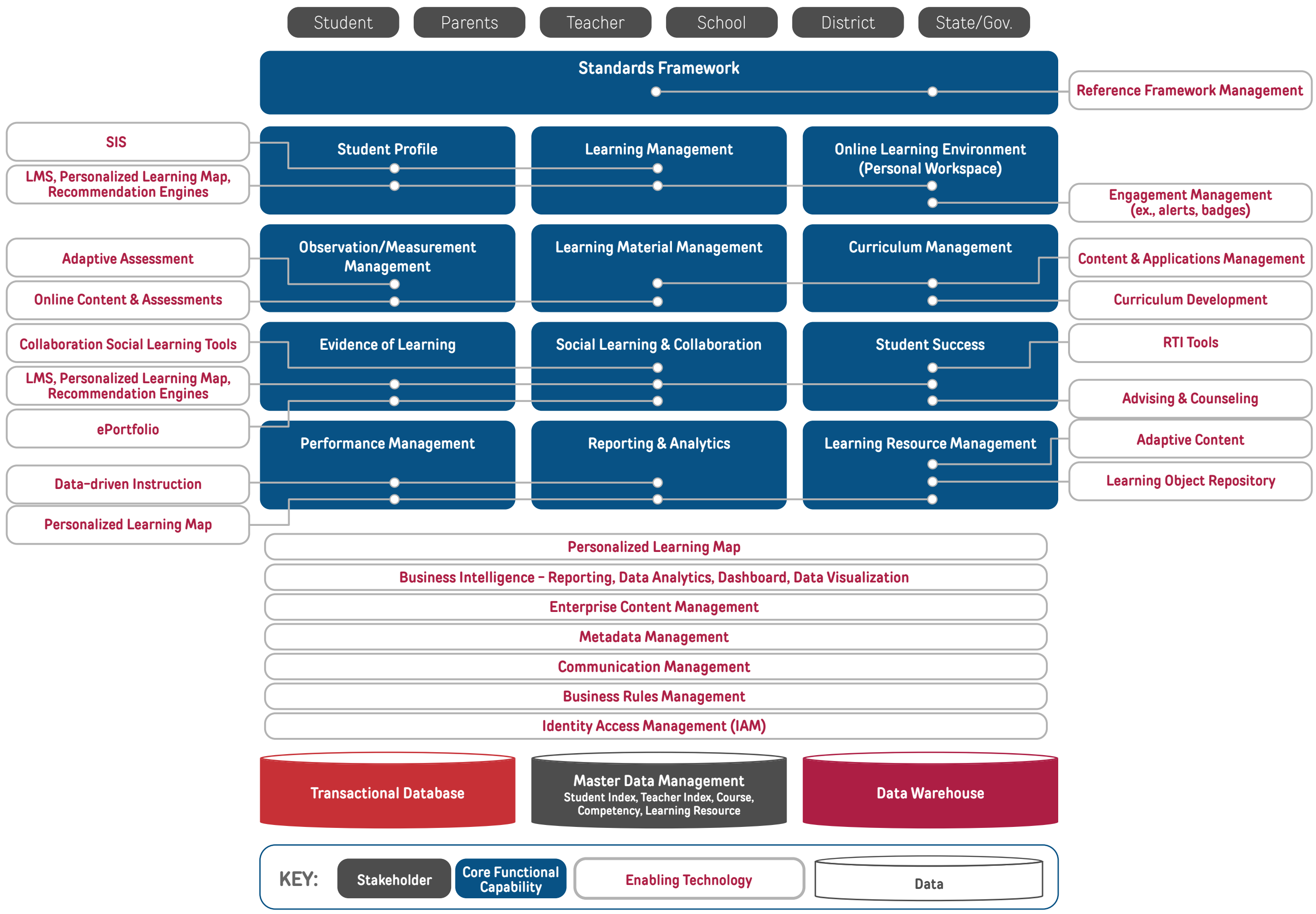


Figure 4. Conceptual Framework: District Core Capabilities for Student-Centered Learning with Enabling Technologies

This requires a comprehensive approach to the required information technology systems, data standards and interoperability standards. Moving robust, consistent, longitudinal, and real-time data and resources seamlessly across multiple systems is essential to a student-centered learning integrated information system. Therefore, it is essential that these information technologies be able to "talk to each other" using the same data standards. This requires that the systems be standards-based and follow interoperability design principles. See Appendix A: Understanding Education Technology Standards for more on this topic.

> ***"Although many approaches have been developed, schools, districts and states have struggled to figure out the best way to address the issue of flexibility, scalability and financial responsibility. These individualistic approaches have been time consuming and costly. A well-designed technology system can be an enormous support pillar for all three of these challenges."***
>
> *Beth Colby*

We have just looked at a conceptual architecture for the overall business capabilities and examples of enabling technologies of a more encompassing system architecture approach. A layered approach to the core functions and enabling information applications should be considered due to the complexity of the tasks. Schools and school systems will need to determine which of these apply to their current and future practices as they move forward in this work. A structured approach to defining this alignment that uses the methods and practices of process improvement and redesign is an effective method for approaching this challenge.

The next section, which presents a detailed, student-centric view of the IT ecosystem for supporting student-centered learning and the analysis of this by implementation approaches, can aid in this thought process.

Section V: A Student-Centric Approach to Student-Centered Learning Information System Design

The importance of student-centered learning for effective education is well established, yet teachers, schools and districts struggle with implementation. To actually put each of these tenets into play requires a whole school and school system transformation supported by a robust, student-centered learning integrated system. We will discuss the design and functionalities of such a system at a high level in this section and in detail in Appendix B: Data and Application Design for a Student-Centered Learning Integrated Information System.

STUDENTS AT THE CENTER AND FEEDBACK

Since a primary objective of a student-centered learning integrated system is to optimize learning for each student, one of the most critical functions of the system involves the delivery of personalized learning experiences with targeted, personalized feedback, many of which will be through the learner's direct interaction with a component of the system or as a combination of online and offline experiences. Whether the experience takes place online or offline, the system must facilitate formative and summative feedback to the learner and teacher from multiple sources.

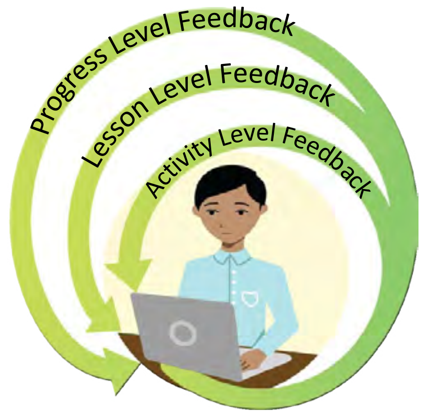
The primary objectives of a student-centered learning integrated system is to optimize learning for each student and to support the instructional processes for teachers and others involved in working with the student.

Learning moves forward through timely, meaningful, actionable feedback. For the purposes of this student-centered learning system design, feedback is broadly defined to include any information provided to the learner that helps correct misunderstandings, reinforce or extend learning or indicate what the learner should do next. Sometimes the feedback comes from a teacher, tutor, peers or software. Sometimes the feedback loop involves the learner recognizing an error and self-correcting or reflecting upon his approach and using the same or different approach in the future.

Technology can greatly enhance feedback loops for learning. In the article "Understanding the promise of personalized learning," Alex Hernandez wrote that feedback "has a powerful impact on student achievement and providing it is entirely within the school's control. In traditional classrooms, teachers are the bottleneck in giving student feedback unless there are other feedback loops students can access directly. In personalized learning environments, students theoretically have access to ample, frequent and actionable feedback from multiple sources, including content, peers and teachers."[12]

The design of the SCL IS assumes that feedback is provided on multiple levels:

- **Activity level** – Formative feedback during a learning experience
- **Lesson level** – Feedback after a learning experience that checks for understanding
- **Progress level** – Feedback on where a student is in relation to learning objectives, competencies, district and state interim and summative assessments, and other measures of progress



Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 5. Feedback Levels

Data from these feedback levels can also be gathered and analyzed to inform instruction, create organizational practices and provide system-level feedback to influence decisions about how the system can be improved over time to better support the learning process for all.

Feedback and use of the data are foundational to the student-centric learning process. The SCL IS has been designed to take full advantage of the use of multiple systems that are needed to support student-centered learning processes and the data from those systems. Now, let's look at the components of the system and how they support the learning process.

MODULAR ARCHITECTURE

A robust, student-centered learning integrated system needs to support the following:

- A reference framework for aligning learning experiences, resources, assessment and reporting to the competencies
- Customized learner profiles that combine data from source systems and input from students, parent, educators and others involved in the student's education and well-being
- Personalized learning plans that are responsive to the learner as he or she progresses and changes
- A variety of learning experiences within and beyond the school setting and calendar and the collection of the associated data to inform student progress
- Access to content, digital resources, human resources and tools through a user-centric interface
- Meaningful, timely feedback during the learning process
- Multiple ways of demonstrating and assessing mastery toward competency
- Relationships, collaboration and communication
- Dashboards that show in real time which concepts and objectives students struggle with, pinpoint at-risk students and enable targeted intervention
- Analytic tools to support data-informed practices (learning, teaching, administration)

This requires that multiple systems that work together to enable the desired functionality. Therefore, the technical design of the student-centered learning integrated system is modular and based on the integration of multiple technologies. The design organizes the SCL IS functionality into these key functional components.

- Online Learning Environment Functions
- Integrated Content, Activities, and Feedback Functions that the learner will access through the Online Learning Environment
- Observation and Measurement Functions
- Evidence of Learning Functions, and
- Social and Collaborative Learning Functions

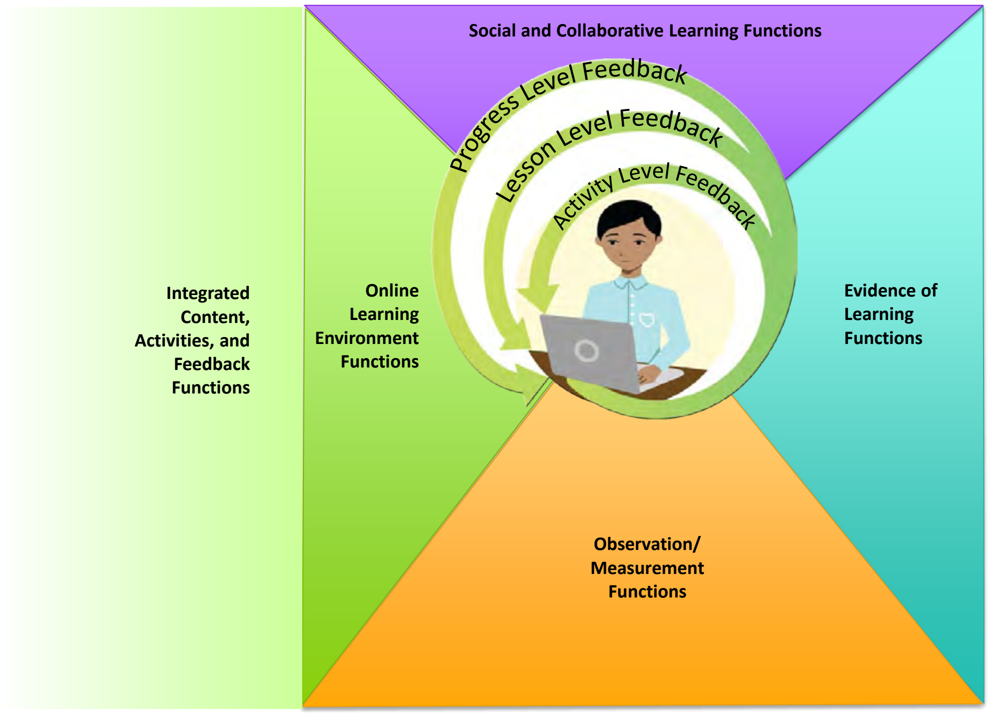


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Figure 6. Key Functional Components

Each of these core functional areas represents high-level functions and includes a variety of functional capabilities and components. In this next section, the functional components will be presented within a broad context. Appendix B: Data and Application Design for a Student-Centered Learning Integrated System provides more detailed explanations.

STUDENT-CENTERED LEARNING INTEGRATED SYSTEM FUNCTIONAL COMPONENTS

The software, services and learning content needed to support student-centered learning must be distributed. In this design, the functions may be provided by different enabling technologies and will require the integration of different teaching, learning and business system applications. In addition, the student-centric learning design above is supported by other system capabilities that are removed from the direct learning experience, but serve in critical supporting roles, such as managing learning resources and educator interfaces plus maintaining the security of personal data. These core functional capabilities that support the district business capabilities are included in the Conceptual Framework: District Core Capabilities for Student-Centered Learning (pages 32-37).

THE ONLINE LEARNING ENVIRONMENT FUNCTIONS AND THE ASSOCIATED INTEGRATED CONTENT, ACTIVITIES, AND FEEDBACK FUNCTIONS

The online learning environment refers to the student's personal online workspace, providing a single sign-on, student-centric user interface. In this personal workspace, the student has access to all the tools, content, assessments and data needed to support the learning process. The online learning environment provides the context from which the learning experience is enabled, and students take ownership of their learning. All other components of the SCL IS that a student needs to use are accessed through this portal. This requires standards-based approaches to single sign-on and content/tools integration.

This personal workspace is one function of systems that traditionally fall into the learning management system (LMS) category. Many LMSs, however, do not meet the design requirements for student-centered learning since they were designed to support teacher-centered, course-centric learning processes rather than student-centered processes. This design focuses on the features needed for the functional requirements of student-centered learning.

Figure 7. Online Learning Environment Supports User Interface and Source System Data Integrations

The online learning environment needs information from the district's source systems to roster students and staff. This is integration point 1 in Figure 7. Generally, the data for what course sections the student is enrolled in and which teachers have been assigned to those classes come from the Student Information System, HR or other systems of record. A student-centered learning system also needs to support assignment of multiple teachers to courses, sections of students, and individual students.

Learning Experience Functions

No single system or source has the rich set of learning experiences or content needed to provide personalized learning at scale. The integrated system must support both online and offline activities; therefore, there will be multiple sources of learning activities and content. The integration of learning activities and content is a critical component of systems integration.

Online activities could range from adaptive, content applications that provide instruction targeted at the needs of the student, to hosted software like a learning game (*Lure of the Labyrinth*), to static content such as text or videos, to collections like *Khan Academy*, to online courses. No matter what the activity is, it needs to integrate into the learning environment. The integrated system makes it look like the content or software is built-in when, in fact, it may be hosted on another server. Each of these includes online touch points that provide an opportunity to collect valuable data to inform teaching and learning.

Supporting offline activities may mean that the system provides instructions for the learner to follow during an offline activity, online tools for completing and submitting the activity as well as assessments to measure learning and give feedback. Tools to support project-based learning (planning, project management, reflection) would be accessed through this workspace. An offline project-based learning activity may be designed with any number of online touch points.

The SCL IS must support learning as a series of logically connected experiences/activities. It facilitates the connection between the discrete experiences on the front end through the personalized workspace, but it depends on a number of behind-the-scenes systems that deliver content and experiences and link them to competencies.

Reference Framework

Student-centered learning is competency-based. So it is important that learning activities, content and assessments are linked to specific competencies. For that we need a component with information about the competency framework. In this design, that information model is called a reference framework. The reference framework functionality can support all kinds of reference frameworks, not just competencies, for example: Bloom's taxonomy levels or Lexile ranges. The reference framework defines what a learner should know or be able to do and defines rules for measures that indicate levels of mastery.

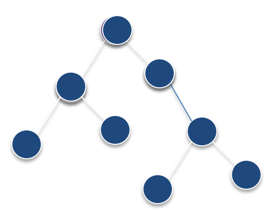


Figure 8. Reference Framework

Competency education requires systems that align learning resources and other data to competencies. The integrated system for student-centered learning must include systems that store information about competencies in machine-readable and human-readable formats

The reference framework will often be based on learning standards adopted by the jurisdiction (e.g., a state or local school district). It may also include standards for habits of learning and indicators for 21st-century skills. It may include additional information about how to measure levels of mastery, more granular competencies (such as process steps that make up a skill) and relationships between individual competencies (e.g., prerequisite/post-requisite relationships).

Reference frameworks are typically defined as a hierarchy of statements with the subject matter context at the top (e.g., Mathematics), one or more levels of classifying statements (e.g., Number and Operations), and one or more levels of competency definitions. They may include recommended and alternative competency pathways.

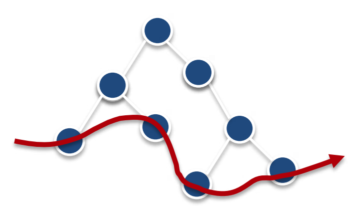


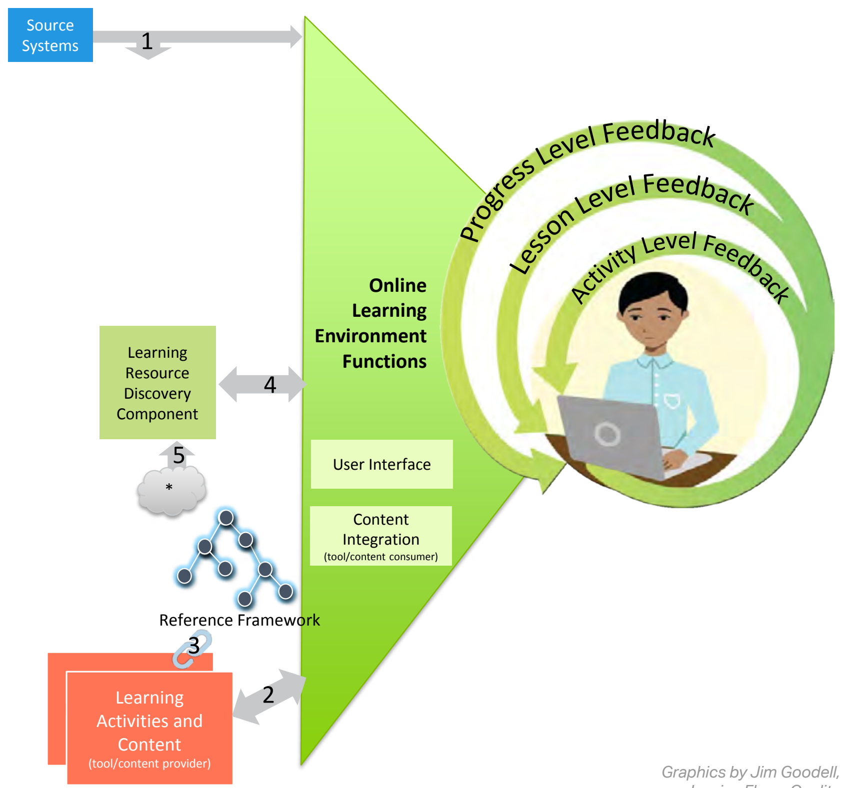
Figure 9. Pathway in a Reference Framework

Competency pathways show recommended or prescribed pathways for student learning, such as what competencies to address before, during and after addressing other competencies. These pathways are defined as a set of associations between nodes in the framework. There could be just one recommended pathway or multiple recommended pathways to address multiple learner profiles.

Learning activities and content are linked to specific competencies (and other taxonomies) through the Reference Framework. The taxonomies in the frameworks also provide the basis for reporting, analytics and learning resource discovery. Learning activities and content linked with competencies in the Reference Framework are accessed through the Online Learning Environment, as represented by integration points 2 and 3 in Figure 10.

Learning Resource Discovery

A SCL IS supports the discovery of a rich variety of learning resources and activities. Unlike teacher-centric models, which provide a fixed lesson plan with the same set of activities for all or groups of learners, the SCL IS provides multiple options to meet each learner's needs and preferences, allowing students to choose from a set of curated activities and resources in pursuit of a learning objective.



Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 10. Reference Framework and Learning Resource Discovery

Digital content, for example curated activities and resources, is often stored in specific digital libraries called Learning Object Repositories (LOR). These systems typically provide a Web interface to allow the searching of education resources through the metadata. A system may include a LOR managed by the organization for locally-developed resources, commercial LOR products and Open Education Resource LORs. The ability to do intelligent searches of these LORs using a single search engine is provided through the learning resource discovery component. This is integration point 4 in Figure 10. Learning Resource Discovery Tools may use a metadata repository that is self-contained or integrated with other sources of learning resource metadata, such as a Learning Registry node. This is integration point 5 in Figure 10.

The learning resource discovery system may be used by: 1) an educator to curate a limited number of activities assigned or offered to the student in a personal learning pathway or playlist, 2) the student to discover resources/activities applicable to the learning objective or 3) a school, district or state to created curated collections for staff, students, and parents.

Assignment/Activity Lists

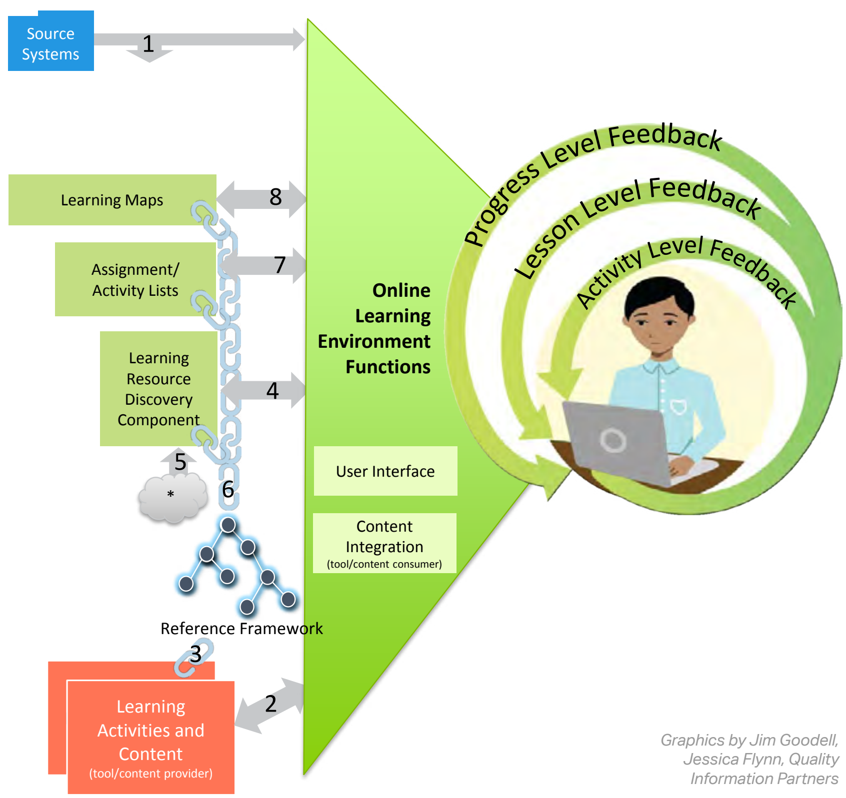
Another component provides assignments and "playlists" for the student. The processes for the personalization of these lists will be discussed throughout the other functional areas. Whether the assignment/activity is a discovered resource, a teacher assigned learning activity or a student-developed activity, it needs to link to the Reference Framework for information about the competencies and other frameworks that the district may have included, such as Depth of Knowledge level or text complexity.

Learning Maps

Learning maps help learners see the bigger picture. The organization will need to define what it wants the learning map to include and display. There are different kinds of "maps" in various products that show where the student is and where the student is going. *Khan Academy* has a map visualization showing recommended paths through math competencies. The learning map is not the student's personalized learning plan. The personalized learning plan pulls the competencies, learning outcomes and sequencing (if any) from the reference frameworks.

Content referenced within Assignments/Activities Lists and Learning Maps link to relevant nodes within a Reference Framework. This is integration point 6 in Figure 10.

Assignments/Activities Lists and Learning Maps are made available within the Online Learning Environment as represented by integration points 7 and 8 in Figure 11.



Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

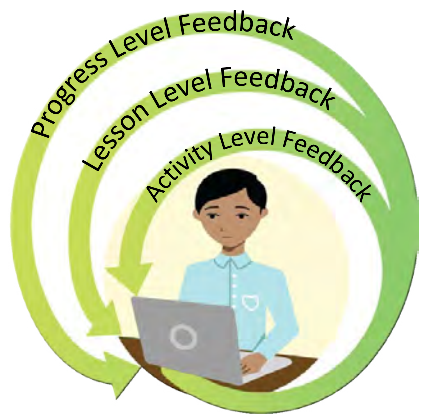
Figure 11. Assignment/Activity List and Learning Maps

OBSERVATION/MEASUREMENT FUNCTIONS AND THE ASSOCIATED INTEGRATED CONTENT, ACTIVITIES, AND FEEDBACK FUNCTIONS

Learning is an iterative process: experience – feedback – experience – feedback. To support the right kind of feedback, the student-centered learning integrated system must track, store and report information about where the learner stands in relation to the learning objectives, while updating the learner specific model in real time. This information serves as the foundation for the Observation/Measurement Functions and Dashboards/Reports in the Integrated Content, Activities, and Feedback Functions.

Systems for Learner Feedback and Guidance

Separate system components are needed to provide feedback to the learner at different levels within the learning process, from different sources such as educators, peers or intelligent algorithms (such as tutoring systems or recommendation engines). Feedback is also included in the processes that support learner motivation and ownership. System components empower learners to support each other's progress and celebrate success. As described previously, feedback is provided on multiple levels: activity, lesson, and progress. Data dashboards (visual representations of student progress in relationship to learning maps) are often used to display progress-level feedback and learner profiles.



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The Learner Specific Model: Mapping What the Learner Knows and is Able to Do

The Learner Specific Model includes information typically referred to as a 'learner profile' data such as preferences, specific misconceptions, habitual mistakes or exemplary practices that apply across learning objectives, such as self-agency skills, as well as information about where the learner stands in relation to the learning objectives and competencies. The model may also include data that help the SCL IS and/or educators determine specific gaps in understanding or performance. There are multiple sources of data that may be used to inform the learner specific model, primarily assessment data, learner experience data and data about artifacts of learning. It serves as the data store for the learner profile and the achievement tracking function.

The Learner Specific Model works hand-in-hand with the systems of measurement and feedback, so the assessment data collected within the model supports multiple purposes:

1. Identifying specific misconceptions/weaknesses observed during a learning experience. (For example, an intelligent tutoring system that uses scaffolding questions after the learner enters a wrong answer to determine the gaps in understanding that led the student to the wrong answer.)
2. Indicating the level of mastery for each target competency at points in time. (For example, an activity after a lesson checks the learner's understanding of a covered concept or skill.)
3. Displaying progress on a competency-based pathway.

The learner specific model keeps track of evidence data from measurements, observations and artifacts that are also linked to nodes in the reference framework. As described earlier, the reference framework is often based on learning standards adopted by the jurisdiction, standards for habits of learning and indicators for 21st Century skills, and additional information about how to measure levels of mastery, more granular competencies and relationships between individual competencies.

The learner specific model shows learner progress in an actionable representation of what the learner knows and is able to do in relation to the reference framework. For each node on the student's pathway in the reference framework, we can assess the learner's level of competency. The circled node in the figure represents a node that has been assessed.

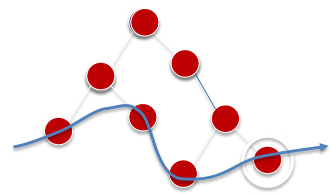

Figure 12. Learner Specific Model

Sources of Data

There are multiple sources of data that may be used to inform the learner specific model, primarily assessment data, learner experience data and data about artifacts of learning. The SCL IS supports obtaining assessment data through the Assessment Subcomponents and learner experience data through the Learning Experience Record.

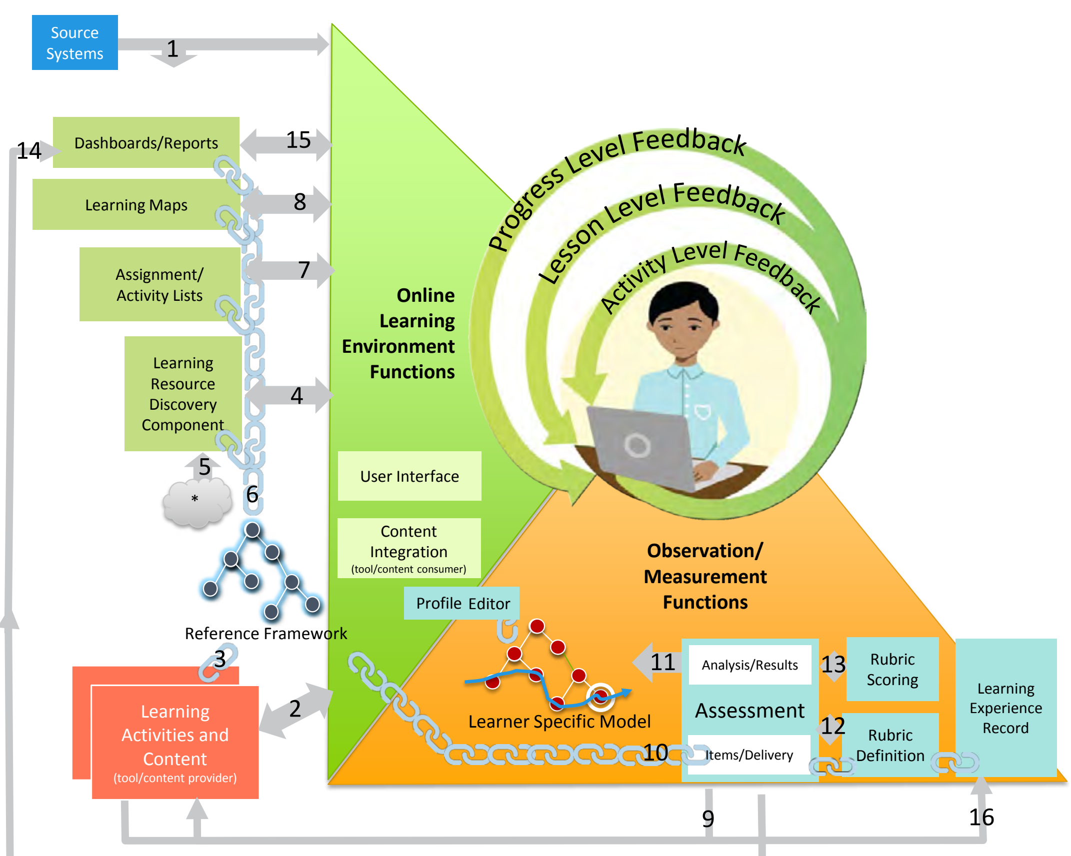

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Figure 13. Learner Specific Model and Data Sources

Assessment Systems

The most common and high-profile assessment data, data from high-stakes assessments, are not the kind of data that are most important for student-centered learning. For competency-based, student-centered learning, we are not concerned as much with an overall score on an assessment as much as what the assessment tells us about the student's ability to do something at a point in time. Furthermore, we want to know if the student got a problem wrong, which wrong answer was given and what that wrong answer might tell us about gaps in the competency being measured. We also want data from a variety of assessments .

Formal assessment systems can be further broken down into components for item and test authoring, item and test delivery, registration, scoring, analysis and results. To support formative assessment, item banks and assessment results are essential components. Since the system is supporting competency-based learning, every assessment item and task should be linked to one or more nodes in the reference framework. This is presented in integration point 10 in Figure 13.

The SCL IS supports packaging up assessment items and tasks for delivery through an online assessment system, embedded assessment engine or project-based learning system that is delivered through the Online Learning Environment. It also supports linking assessment results with the delivery of Learning Activities and Content, integration point 13.

Rubrics

Some assessment tasks require rubrics for scoring; therefore, the system needs to include the ability to host rubric definitions. Furthermore, it needs to support linking the results of an assessment to criterion levels within a rubric. This is presented in integration points 12 and 13 in Figure 13. The use of rubrics is an important component for project-based learning and portfolios, both of which are aspects of the Evidence of Learning Function.

Learning Experience Record

Experience data is the data captured while students engage in learning experiences and online activities and is collected in the Learning Experience Record, integration point 16 in Figure 13. When students engage in online learning experiences, every action that the student takes can become valuable data for use by teachers and the SCL IS to inform learning. It is impossible for a teacher to observe every learning experience for every student, but the experience data captured during hours of online learning experiences can give teachers at-a-glance indicators that may be used to optimize learning.

These "clickstream" data are used to support student-centered learning as a source for predictive analytics, early warning systems and customized feedback to the learner. These experience data are also linked to achievement/ competency data as detailed evidence of learning pathways and progress over time.

Assessing Soft Skills, Attitudes and Habits of Learning

Soft skills and other success factors, such as the learner's sense of ownership for learning, can be measured and become valuable inputs into the SCL IS. Some indicators, such as changes in attitudes about subject matter over time and the student's fixed or growth mindset, may be determined through surveys and other assessment instruments. Some indicators can be derived by analysis of patterns in experience data. Sometimes these indicators are built into competency frameworks.

INTEGRATED CONTENT, ACTIVITIES, AND FEEDBACK FUNCTIONS —DASHBOARDS AND REPORTS

The results of assessments need to be reported back to the student through Dashboards and Reporting, integration point 14, and accessed through the Online Learning Environment, integration point 15. The Online Learning Environment provides the content and assessments that enable the learner to progress through competency-based pathways. From the learner's point of view, all of the online feedback and guidance directing this progression is "in" the Online Learning Environment which is the student's personal workspace. In reality, there may be separate systems supplying the content, assessments, learning maps, alerts, recommendations, social and collaborative learning tools and feedback to scaffold the transition between discrete learning experiences. The PLP in the Dashboard/Reports includes the right amount of information to provide structure so the learner doesn't get lost, while supporting more than one path to a learning objective. The SCL IS supports the integration of these separate systems.

EVIDENCE OF LEARNING FUNCTIONS

The Evidence of Learning Functions support the achievement tracking of milestones reached by the student with links to the evidence and artifacts of that learning.

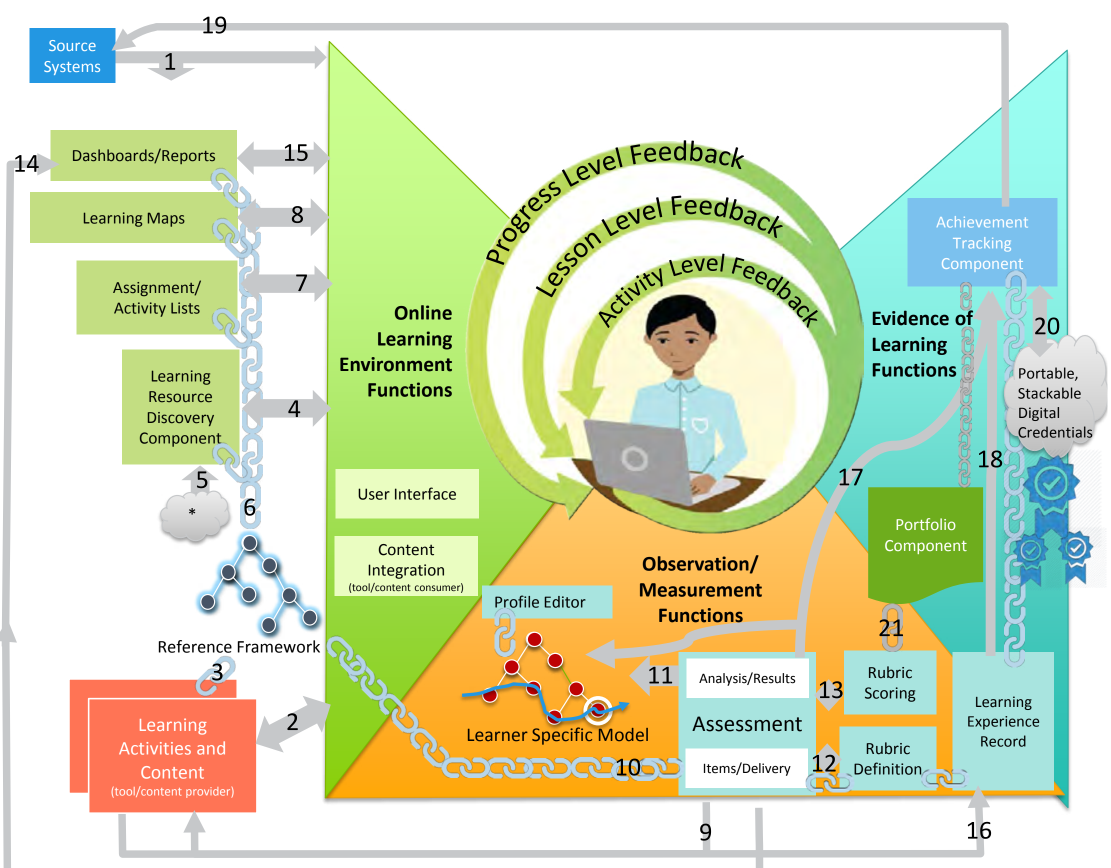

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Figure 14. Evidence of Learning Functions

Achievement Tracking Component

The Achievement Tracking Component is based on data from the Observations/Measurements Functions as well as supporting the inclusion of data from verifiable electronic records of a person's achievements or qualifications from organizations outside of the school setting, in order to get a complete picture of learner competencies. The Achievement Tracking Component uses Assessment Results, Learning Experience Record Data and other Learner Specific Model data, integration points 17 and 18 in Figure 14.

Portfolio Component

The Evidence of Learning Functions also provides the portfolio functionality of being able to store artifacts of learning and link the evaluation of those artifacts to a rubric score. Artifacts of learning are digital representations of work products or digital proxies of tangible work that give evidence to what a student has learned, for example a written report, multi-media presentation, video or recordings of live presentations and discussions. Artifacts of learning are only meaningful in the SCL IS when linked to the reference framework and a system of measurement, i.e., what specifically does the artifact show about student learning, what reference framework learning objectives have been addressed and does this contribute to the measurement of learning for those learning objectives. The SCL IS must include components for capturing artifacts of learning, evaluation of the artifacts and linking the artifacts to competency definitions in the reference framework. The Portfolio Component stores artifacts of learning and links the evaluation of those artifacts to a rubric score, integration point 21 in Figure 14. The Achievement Tracking Component can include data from the rubrics and link to the actual portfolio artifacts as evidence of achievements, integration point 17.

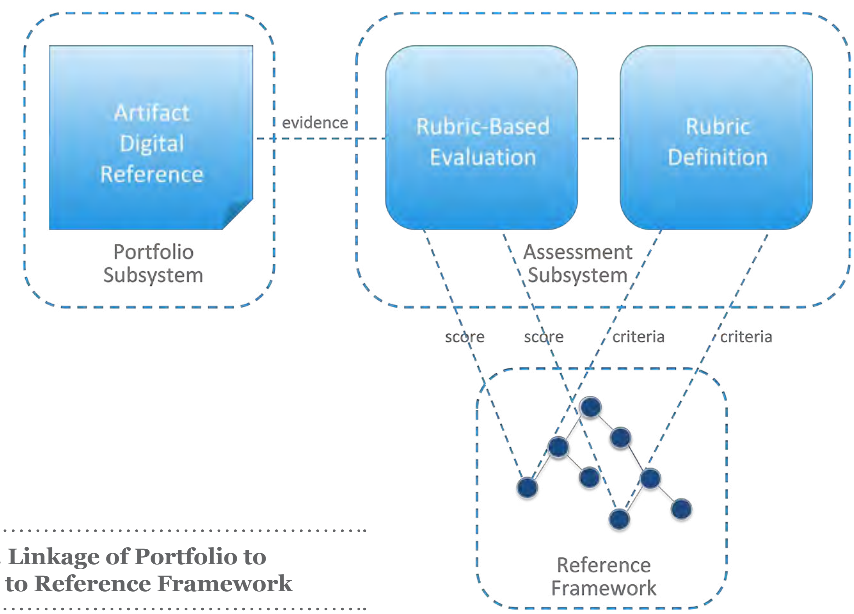

Figure 15. Linkage of Portfolio to Assessment to Reference Framework

Students can also use this function to demonstrate learning through presentations using student-developed and existing artifacts organized into collections in the portfolio. The student and/or teacher can associate a rubric with presentation and the student, other students, teachers and others can complete the rubric. Students can share their artifacts, presentations and portfolios electronically.

The evaluation of the artifact may be used in multiple ways:

1. To identify gaps (looking for specific weaknesses, inform feedback)
2. To recognize progress (recognize when certain thresholds have been met) for a specific competency
3. To recognize competency completion (as part of multiple measures)

Evaluation of Evidence of Learning

Assessments of performance tasks that take place offline should be captured online. For example, a mobile app could be used by a teacher for real-time evaluation of a learner's performance on a task. It is important that data captured to evaluate offline activities include more than just summative scores of the activity. For example, a teacher assessing a student's oral reading fluency may mark up a passage and use an instrument such as DIBELS® Oral Reading Fluency to calculate a fluency score (word count per minute). Recording the fluency score online is helpful, but it may leave out important formative data, such as the mark-up indicating whether or not the student recognized an error based on context and self-corrected. When a rubric is used, the data should include the detailed assessment for each criterion, not just the overall score.

Portable Stackable Digital Credentials

"Stackable" achievements/credentials refer to the ability to combine smaller achievements into larger achievements—for example, the set of learning objectives required to complete a competency, competency achievements adding up to course completion and multiple courses combining into a certificate or diploma. The Achievement Tracking function needs a way to pull in verifiable electronic records of a person's achievements or qualifications from other sources in order to get a complete picture of learner competencies. A transcript with letter or number grades from another school system is not informative enough for student-centered learning. The data from Portable Stackable Digital Credentials is linked to the Achievement Tracking Component, integration point 20.

SOCIAL AND COLLABORATIVE LEARNING FUNCTIONS

The Social and Collaborative Learning Function supports synchronous and asynchronous communication, including tools like discussion boards, chats, webinars, texts, email, Twitter and Facebook-like tools that enable students to interact with each other, teachers and others involved in the student's education. It may also include project-based learning tools that allow students to work collaboratively with others based around projects. Online collaboration and communication tools also provide the means for educators and peers to give feedback to the learner and to fill gaps in understanding. This communication can be used with online or offline learning activities—live or after the activity. The Social and Collaborative Learning Functions are accessed through the Online Learning Environment, integration point 22.

> ***The current LMS is often designed on the transmission model of education—a mechanism to transmit syllabi, content, and assessments. This process is important for the management of the course, but equal time must be given to collaboration, a true learning dimension."***
>
> *(The Next Generation Digital Learning Environment: A Report on Research, EDUCAUSE Learning Initiative, April, 2015)*

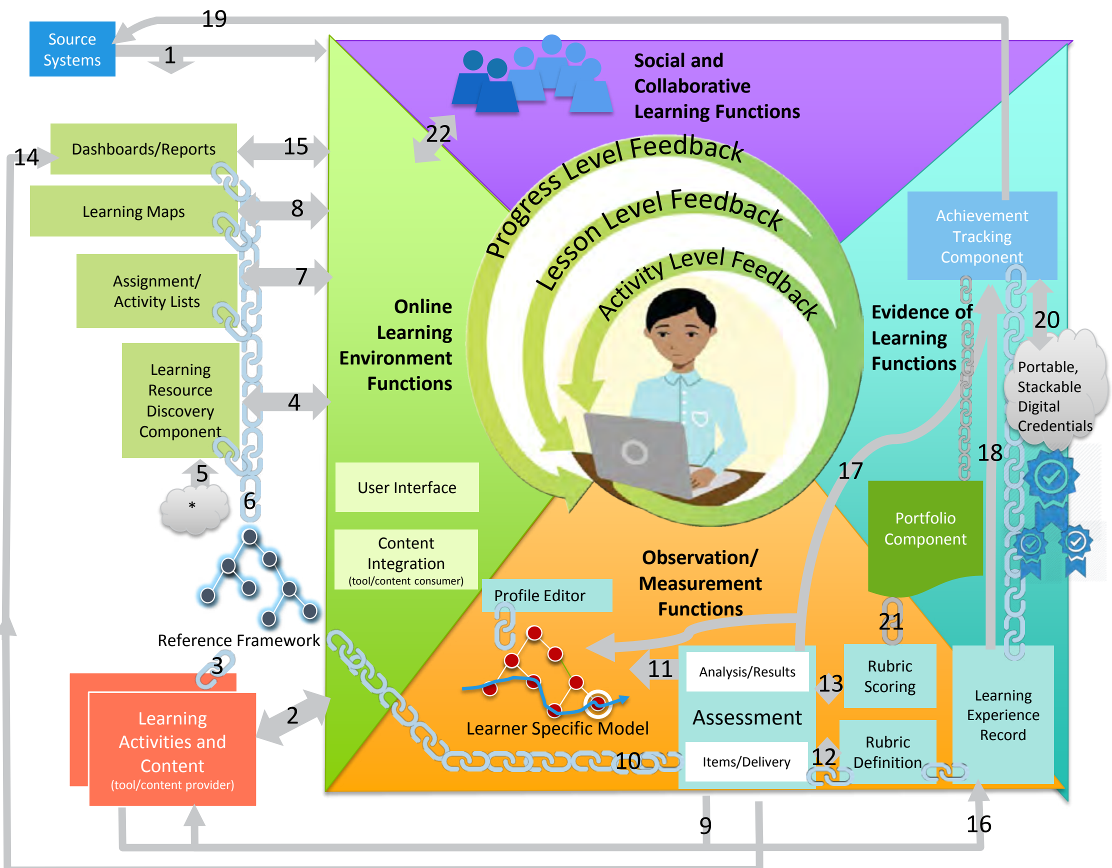

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Figure 16. Social and Collaborative Learning Functions

ADDITIONAL INTEGRATED CONTENT, ACTIVITIES, AND FEEDBACK FUNCTIONS

Recommendation/Analytic Engine Components

The Recommendation/Analytic Engine Components are components that use business rules and technology-like inference engines. Technologies, such as analytics engines and inference engines, work within and with other components such as Learner Specific Model and Achievement Tracking Component to give feedback to the learner in various ways, such as dashboards, reports, alerts and real-time feedback presented within learning activities, integration points 23, 24, and 25. It pulls data from the Reference Framework, integration point 26. It sends data to Learning Maps to inform recommended pathways (29), to Assignment Lists (30), and to the Learning Resource Discovery component as cues for filtering based on learner needs and assertions about the quality of learning resources based on actual use (31).

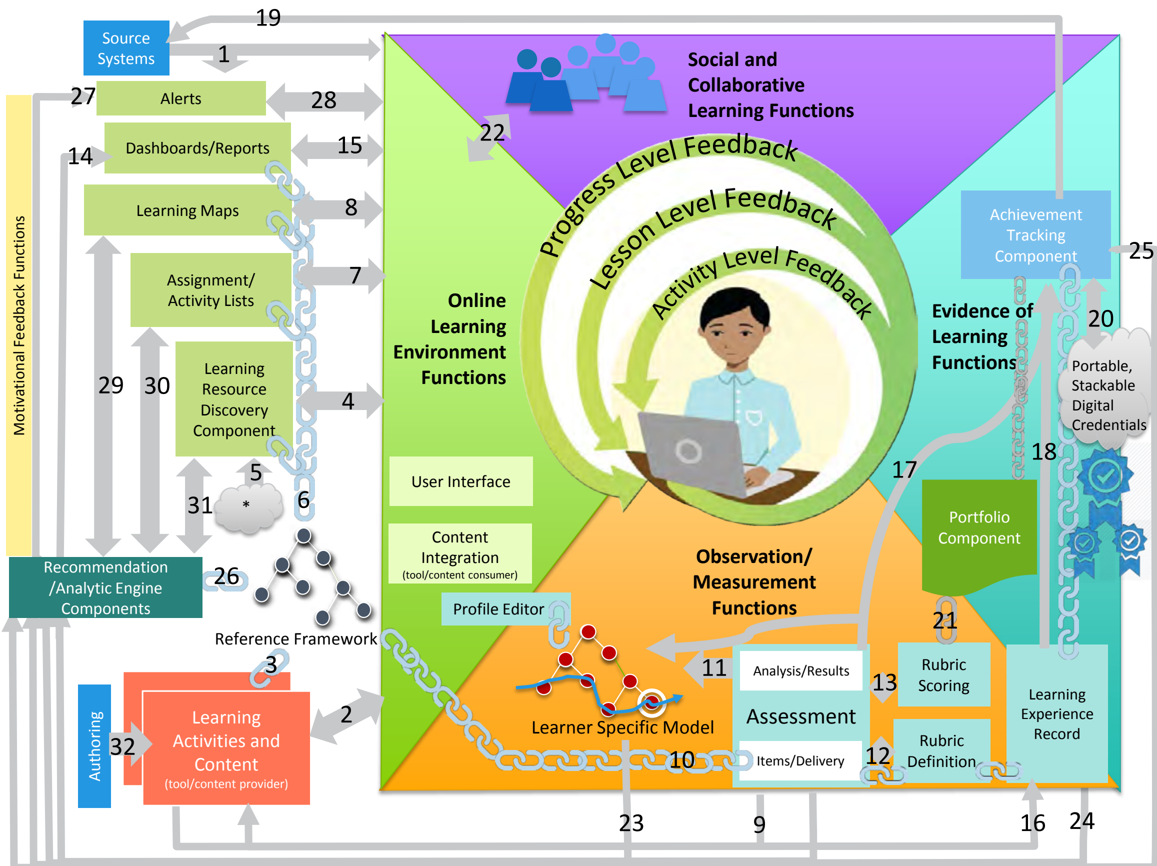

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Figure 17. Recommendation/Analytic Engine Components and Motivation

Alerts

Alerts are used to send email and text messages to users regarding performance, due dates, new information. The Recommendation/Analytic Engine Components and separate Student Motivation feedback systems may send data to trigger Alerts, integration point 28.

Motivational Feedback Functions

The personalized workspace is also a portal to the display of motivational feedback. Student motivation can include things like badges and awards, but the best systems of motivation will be personalized along with learning. Student motivation is more complex than offering gold stars. Different things motivate each learner.

Authoring

This system will not work without components such as Authoring tools. Any role granted permission within the system can author content, including students. Whether these content objects are made available to others within the system should be a policy issue, rather than a technical one. This is integration point 32.

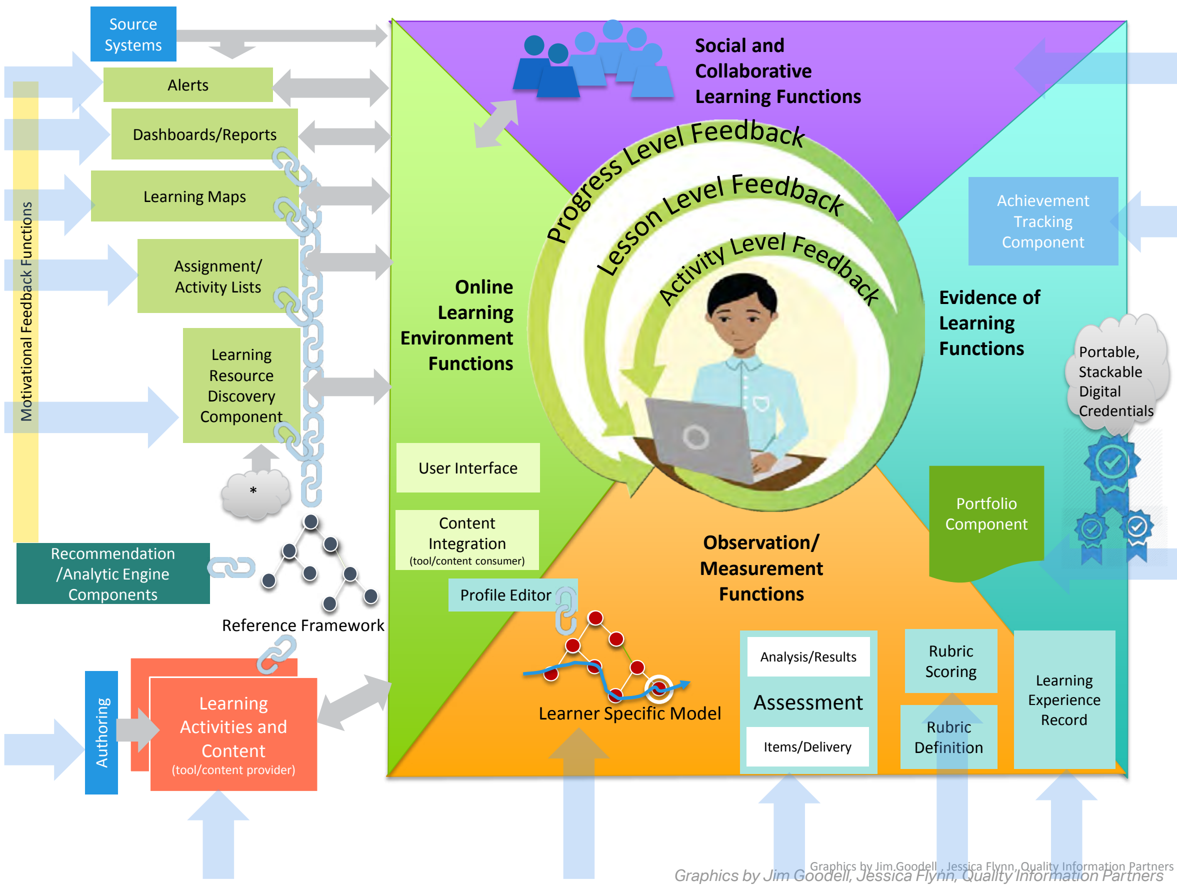


Figure 18. Teacher Interaction Points with the System

TEACHER INTERACTION

The views presented previously have been from a student-centric view of the functions. In the following graphic, the blue arrows show how educators might interact with some of the same components that are shown for the student. Different systems may bundle functional components differently, but this model shows the key parts and how they need to integrate. The design depends on the use of data and technical standards to support integrations.

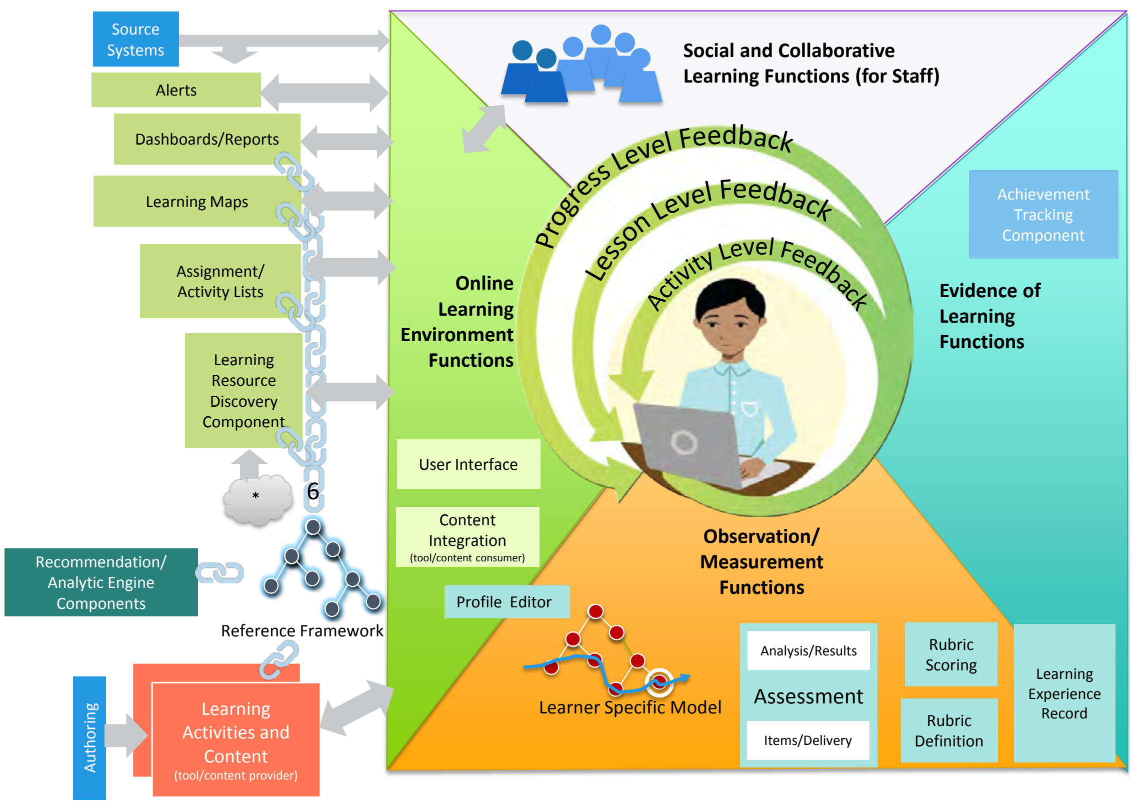
PRIORITIZING AND ASSESSING REQUIREMENTS AND SYSTEMS

According to the Center for Educational Leadership and Technology (CELT), an integrated, multi-dimensional information system can tie together current education reforms with effective and creative uses of technology in ways not possible using disparate systems.[13] In determining what systems to use and integrate, an organization must consider what it wants to accomplish through the use of these systems and how this aligns with the organizational vision, educational goals and strategic plan. It is also important for state, district or school leaders to determine how comprehensive they and their stakeholders want the information solution to be over time. Having a good understanding of what the end users' current and future functional needs are—and expressing these in scenarios or personas—will help inform the requirements of a RFI or RFP. The descriptions in this paper could help inform those considerations. Consider these implementation examples:

Mastery-Based Online And Blended Learning

An organization is implementing its student-centered learning by deploying mastery-based online and blended learning. The digital content for these experiences consists of locally-developed, OER digital resources and commercial applications. Assessments are both centrally- and locally-developed and include performance tasks that are scored using rubrics. The organization is tracking achievement according to mastery of learning targets and rolling these up into competencies.

Students have personalized learning plans and digital playlists that are based on what the students need to learn within content bands. Social and collaborative learning is done primarily in face-to-face settings. They are not using portfolios or project-based learning as system-wide initiatives. The organization wants to include social and collaborative learning functions for students in the future, but for now it wants to include these functions for staff only.



Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

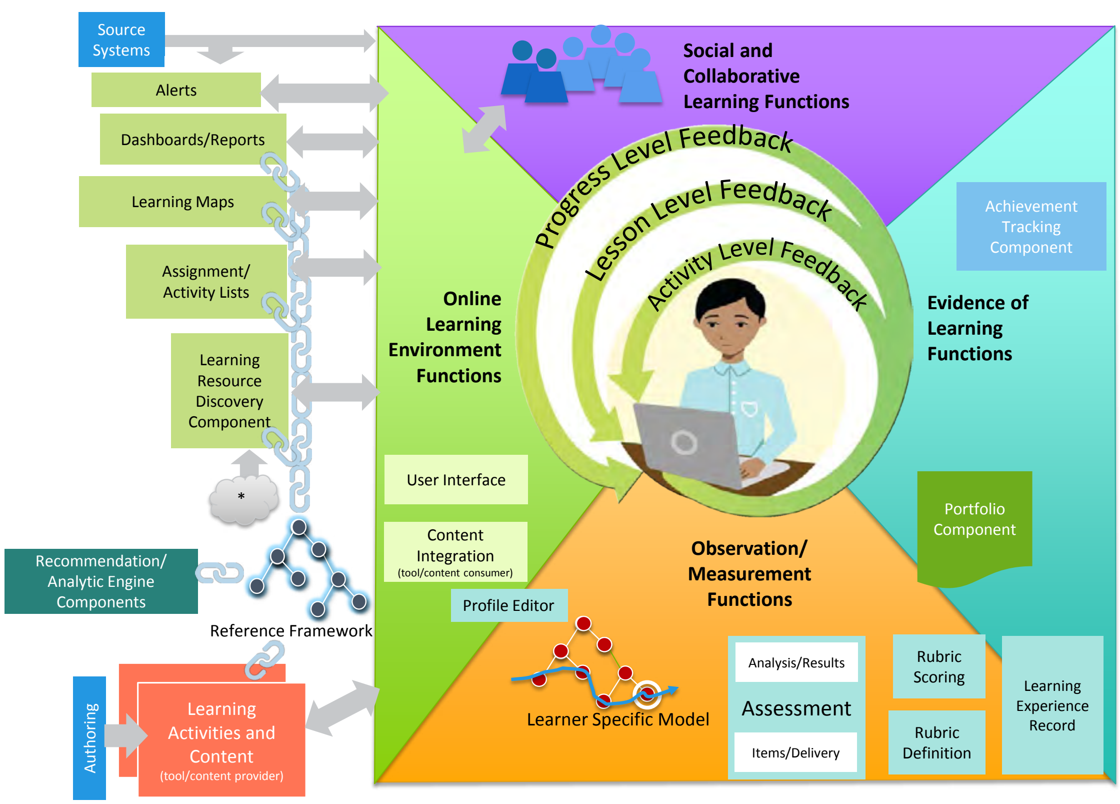
Figure 19. Mastery-Based Online And Blended Learning

The essential functional components that this organization would need to consider include the reference framework, learning activities aligned to reference framework, assessment system, learner model, achievement tracking, learning resource discovery, learning maps, dashboards/reports, assignment/activity lists as well as social and collaborative learning. E-Portfolios and pulling in external credentials and badges are not part of the current focus

.

Project-Based Learning

An organization is implementing its mastery-based learning using project-based learning supported by the use of digital content that is locally developed, OER digital resources and online library/research applications. They use interim assessments based on student progression. They are tracking achievement according to the master of learning targets and rolling these up into competencies. Students are using portfolios and project-based learning as part of a system-wide initiative. They have personalized learning plans and use these plans to co-develop their projects with teachers, peers and, in some instances, external mentors or internship supervisors.



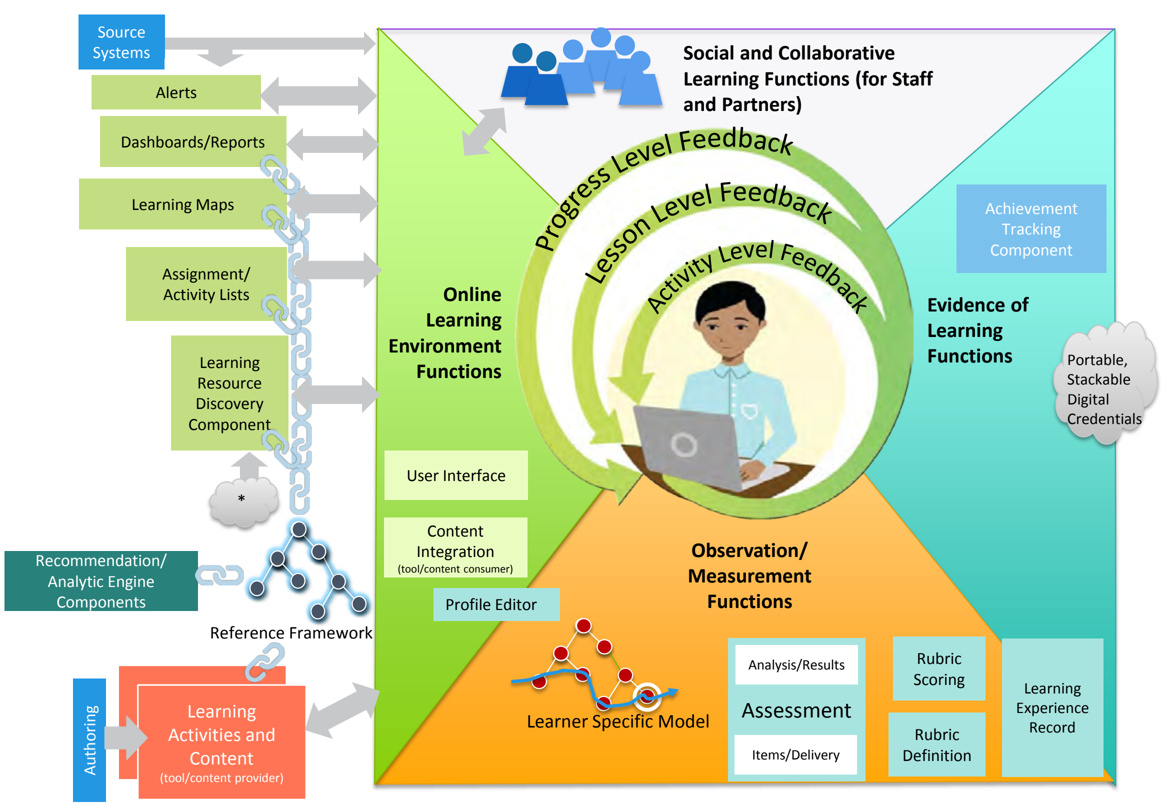
Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 20. Project-Based Learning

The essential functional components that this organization would need to consider include the reference framework, learning activities aligned to reference framework, assessment system, learner model, achievement tracking, learning resource discovery, learning maps, PLPs, portfolios, dashboards/reports, and social and collaborative learning, with an emphasis on project-based management tools.

Online And Blended Learning And External Partnerships For Technical Training

An organization is personalizing its learning for over-aged, under-credited students using online and blended learning plus external partnerships for technical training. The digital content for these experiences involves locally-developed and OER digital resources, commercial applications, and community college and technical training courses. They are tracking achievement according to mastery of learning targets and rolling these up into competencies within courses. Students have personalized learning plans that are based on what courses the students need for graduation and what they need to learn within the courses. Social and collaborative learning is done primarily in face-to-face settings. They are not using portfolios or project-based learning as system-wide initiatives, but they are pulling in external credentials as part of the current focus. The organization wants to include social and collaborative learning functions for students in the future and for now wants to include these functions for staff and external support partners.



Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 21. Online And Blended Learning And External Partnerships For Technical Training

The essential functional components that this organization would need to consider include the reference framework, learning activities aligned to reference framework, assessment system, learner model, achievement tracking, learning resource discovery, learning maps, dashboards/reports, assignment/activity lists, social and collaborative learning for staff and partners, and portable, stackable digital credentials.

What Is Needed For Every Model

Consistent across all three of these options are these core functions: the online learning environment, the reference framework and learner specific model, learning activities aligned to the reference framework, assessment and rubric systems, achievement tracking, learning resource discovery, learning maps, dashboards/reports and assignment/activity lists. Considering how these core functions relate to enabling technologies would be the next step in assembling an integrated system.

Enabling Technology	Mastery-Based Online And Blended Learning	Project-Based Learning	Online And Blended Learning And External Partnerships
SIS or some system of record	●	●	●
Reference Framework tools and Learning Maps	●	●	●
Online Learning Environment (typically LMS)	●	●	●
Recommendation Engines	●	●	●
Learner Profile (all kinds of flavors, often part of LMS, but the need to bring data in from systems outside of the system needs to be dealt with; also, who can add to the profile, who manages it)	●	●	●
Personalized Learning Plans (often part of LMS, but the need to bring data in from systems outside of the system needs to be dealt with)	●	●	●
Assessment (could be part of LMS functionality or separate system, need to bring data in from multiple systems in reporting and analytic tools)	●	●	●
Online Content— Authoring Tools, Learning Object/Content Management systems (integration, discovery and metadata issues to be considered)	●	●	●
Portfolio		●	
Project-Based Learning Management		●	
Data dashboards (Need to bring data in from systems outside of the system needs to be dealt with; issue is what data, for what user, for what purpose, must make sure student facing data is present; consider whether data is summative assessment data or just-in-time progress data or both)	●	●	●
Achievement tracking applications (if part of LMS, how is achievement outside of the LMS tracked and reported)	●	●	●
Analytics	●	●	●
Advising and counseling tools			●

Some examples of enabling technologies discussed in the conceptual business capabilities architecture are listed below. Different products bundle these functions in different ways—native to the product, integration with other products provided by the developer and integration with other products provided by different developers. Major considerations include: how these are integrated, the consistent use of data standards, what data is collected, how and where, and how this data flows back into the integrated system.

Depending upon a school's or school system's student-centered learning model, they may not need all of these functional components and related enabling technologies. However, there are some essential functions for supporting competency-based, personalized learning. These include:

» reference framework and learner specific model
» digital learning activities and resources aligned to the reference framework
» assessment and rubric systems aligned to the reference framework
» achievement tracking aligned to the reference framework and learner specific model
» learning resource discovery aligned to the reference framework
» learning maps aligned to the reference framework
» dashboards/reports aligned to the reference framework and learner specific model
» assignment/activity lists aligned to the reference framework and learner specific model
» analytics systems

Since much of student-centered learning is project-based, the portfolio component is a recommended (but not essential) function. Some applications combine portfolio functions with functions specifically needed to support project-based learning, such as task assignment and tracking.

The Recommendation/Analytic Engine Functions and Motivational Feedback Functions are using emerging technologies, and organizations may want to explore these or pilot them prior to full-scale implementation. There is a significant amount of thinking and process work, as well as actual set-up, which needs to be done when implementing these.

Appendix B: Data and Application Design for a Student-Centered Learning Integrated System provides a detailed, in-depth description of this system, its components, and the data and technical integration standards needed.

Section VI: Using this Information

RFI/RFP IMPLICATIONS

An organization can phase in functionality but should plan for immediate and future desired functionality in an RFI or RFP so they don't outgrow a system in a short period of time. In a workshop at the 2015 iNACOL Symposium, a participant described how, at the end of one year of using online and blended learning, their organization realized that they wanted to move forward with implementing personalized learning supported by online and blended learning and the use of authentic learning experiences. However, their system was not designed to meet this newly desired functionality. It had been designed to support traditional online course delivery that did not include personalized learning plans, robust collaborative tools or analytics.

Using the LMS as an example of planning for future needs, Ovum, a technology advising company, writes that the basic LMS offers simplicity but might not be a long-term solution. A basic LMS frequently does not include features that support student engagement, personalized learning plans, learner profiles or the enabling of teachers and students to personalize their learning experience in meaningful ways. Ovum advocates for more advanced LMSs, called integrated learning platforms. Nicole Engelbert wrote, "Openness, extensibility, and the coherent integration of functionality to drive higher-quality learning experiences characterize integrated learning platforms, which is inherently tied to managing and improving performance outcomes. Analytics and reporting empower a more dynamic learning environment where content and pedagogy change according to a learner's specific circumstances."[14] Ovum outlined some of these considerations in a table in its publication, "Making the right choice for your institution's long-term online learning needs: Differentiating through an integrated learning platform (ILP)", Ovum Consulting, 2014.

Use a rubric to understand solution differences and prioritize needs

	Y/N	Basic LMS	LMS Plus	Integrated learning platform (ILP)
Critical functionality		Basic course management and learner collaboration tools	Integrations with 3rd-party providers to round out basic functionality	Native tools for course management and learner collaboration, including video and document viewers
Content availability		Course content available online only, within the LMS	Course content also available via mobile device/app	Content extended via e-textbook platform
Delivery		Cloud service, continuous delivery – depends on solution		
Mobile		No mobile applications	Designed for mobile and also provides task-specific apps	Adds offline capability for access in low/no-bandwidth areas
Accessibility and usability		Basic Level Accessibility	Gold Level Accessibility	Recurring Gold Level Accessibility and Award Distinction
Extensibility		No APIs	APIs available for individual, institutional, and partner use	Extensive partner network supports integrations utilizing APIs
Curriculum management		Course-level content collections	Learning object repository allowing for content re-use	Open learning repository with course materials and third-party content
Integration		Closed		Open ecosystem and APIs
Reporting		Basic assessment and grading	Basic data can be exported	
Alerts		Notifications and alerts must be sent manually by the instructor	Pre-defined events trigger automatic notifications/alerts	Additional custom alerts based on performance- or activity-based events

Monitoring user activity		Basic access and grade monitoring	Limited information in report format (no visualizations)	Realtime data visualizations showing objective attainment, course/content access, performance, and participation
Monitoring classroom dynamics		No built-in monitoring tools	Visual attendance tools	Realtime visualization using Seating Chart including visual attendance and participation tracking
Predicting student performance		None	Course predictions based on pre-defined criteria	Ensemble model based on previous offerings of a course for more accurate predictions
Longitudinal data collection		None	Exportable for storage outside the LMS	Data warehouse for long-term data storage, allowing institutions to see trends over time
Customization		Consistent look and feel with limited customization options	Limited branding capabilities; users may customize email notifications	Complete branding control via flexible navigation, banners, widgets, etc.; user-selected language, font, and accessibility options
Personalized teaching		Pre-defined course structure and progression	Limited opportunities to customize course structure, content visibility	Instructors can customize content, look/feel, and visibility of course components
Personalized learning		One-size-fits-all progression through a course	Differing due dates or special access for individual students	Allows student choice and flexible pathways enabling a unique experience based on individual student preferences
ePortfolio		No learner-controlled space	Learner spaces to collect and share learning artifacts within and external to a course	Full-featured ePortfolio toolkit to create, share, and assess portfolio artifacts within an institution and via social networks; includes ongoing access after graduation to support lifelong learning
Adaptive learning		No adaptation	Integration with 3rd-party content or adaptive engine providers for pre-defined paths based on performance	Course adaptations available via release conditions or adaptive engines and initiated by instructor (planned learning paths), student (choice), or based on performance

Source: Ovum

Implementing student-centered learning is a complex transformation process that takes extensive planning and commitment, professional development and support for all involved. Chunking implementation and growing organically according to need or program model will be essential. Using an integrated student-centered learning system can make it more manageable and effective if the instructional purposes of the systems are clearly understood and training and support are provided using a growth mindset and continuous improvement process.

STANDARDS AND INTEROPERABILITY

Student-centered learning will require integration of different teaching, learning and business system applications. Using consistent data standards and establishing interoperability between these applications will enable data to flow more seamlessly. Standards are critical, especially at the points in which separate systems need to integrate and the data from those systems need to interoperate. All of these integrations require an organization to have a plan for mapping privacy and security requirements, login protocols, shared field names and content access across the multiple systems. “Information systems that are standards-based and use open APIs are better positioned for rapid implementation and development than systems that have not been developed using interoperability standards. This is often a major consideration for organizations.”[15]

Numerous technical standards exist within the educational space to support interoperability. In Appendix A: Understanding Education Technology Standards, Brandt Redd presents a model for understanding education data standards and technical standards. Appendix B provides an in-depth discussion of the standards as they relate to each of the points of intersection within this design.

Section VII: Conclusion

"Student-centered approaches are based on a wealth of recent empirical studies into how students learn, including important lines of research into brain development, motivation, creativity, persistence, self-regulation, the application of knowledge to real-world problems and other topics."[16] It encompasses personalized learning, competency-based education, anytime, anywhere practices and student ownership. How districts and schools implement student-centered learning varies greatly according to the organization's philosophy and the needs of the students.

Technology can play a powerful role in the implementation of student-centered learning if it's used for empowering students and learning teams. Layering traditionally designed technologies on learning environments will not create the innovation needed. Technologies designed to support a teacher-centric, time- and location-bound approach can hamper innovation, as users struggle to learn and teach in an environment not designed to meet their needs.

A robust, integrated student-centered learning system has the potential to advance teaching and learning if the system is used to support the implementation of student-centered learning as part of a systemic, instructionally-focused plan.

In scaling the transformation of education, it is essential to have access to data and resources in intelligent, user-friendly interfaces that take advantage of advanced analytics and adaptive learning capabilities, support social and collaborative learning, and support, track and monitor student progress towards mastery of competencies. Without integrated information systems designed to support student-centered learning, the adoption of this educational approach will be slower in establishing the new models and improving outcomes.

The concepts in this paper can also be extrapolated to apply to other instances in which technology is used to support education. Implementing technology in thoughtful ways will make for smoother transitions in the future—designing your integrated system in a modular, interoperable way can make it possible to add new functionalities when needed without having to reinvent everything.

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Appendix A: Understanding Education Technology Standards

Written by Brandt Redd

When developing or deploying an educational technology initiative, there are multiple standards organizations and numerous standards to select from. Which are applicable? Which standards should be supported by the product you choose? And, is it realistic to expect plug-compatibility between products?

Considerable benefits to applying standards exist. For product developers, the use of existing data models can shorten product development time and improve integration with partner products. For consumers, the use of standards by their suppliers reduces the cost of integrating products into a coherent solution. But to realize these benefits one must first discover which standards are applicable.

AN EDUCATION STANDARDS MATRIX

The matrix in Figure 22: An Education Standards Matrix plots the most commonly used education standards across two dimensions. The horizontal dimension represents layers in the technology stack that support data storage and communication. The vertical dimension represents a taxonomy of standards and the needs that they address. The two dimensions are described in greater detail later in this appendix.

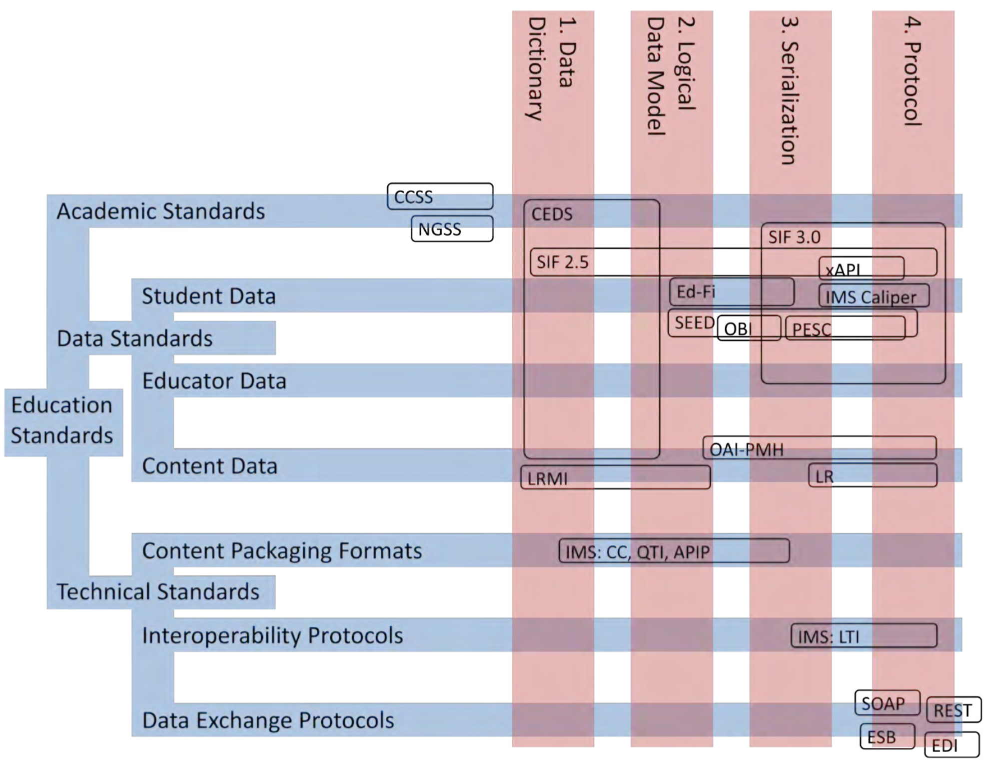

Figure 22. An Education Standards Matrix

Standards people love acronyms, and every one of these standards has an abbreviation. Table 1 Education Standards translates the acronyms into names with links to the corresponding initiatives.

Table 1 Education Standards

- CCSS: Common Core State Standards - http://www.corestandards.org/developers-and-publishers/
- CEDS: Common Education Data Standards - http://ceds.ed.gov/
- Ed-Fi: Ed-Fi Alliance - http://www.ed-fi.org/
- EDI: Electronic Data Interchange - http://en.wikipedia.org/wiki/Electronic_data_interchange
- ESB: Enterprise Service Bus - http://en.wikipedia.org/wiki/Enterprise_service_bus
- IMS CC: IMS Common Cartridge- http://www.imsglobal.org/cc/
- IMS LTI: IMS Learning Tools Interoperability - http://www.imsglobal.org/lti/
- IMS QTI: IMS Question and Test Interoperability - http://www.imsglobal.org/question/
- IMS Caliper Analytics™: http://www.imsglobal.org/activity/caliperram
- LR: Learning Registry - http://learningregistry.org/
- LRMI: Learning Resource Metadata Initiative - http://www.lrmi.net/
- NGSS: Next Generation Science Standards - http://www.nextgenscience.org/
- OAI-PMH: Open Archives Initiative – Protocol for Metadata Harvesting - http://www.openarchives.org/pmh/
- OBI: Open Badge Infrastructure - http://openbadges.org/
- PESC: Postsecondary Electronic Standards Council - http://www.pesc.org/
- REST: Representational State Transfer - http://en.wikipedia.org/wiki/Representational_state_transfer
- SEED: State Exchange of Education Data - http://www.ncpublicschools.org/data/seed/
- SIF: SIF Association - http://www.sifassociation.org
- SOAP: Simple Object Access Protocol - http://en.wikipedia.org/wiki/SOAP
- xAPI: Experience API - http://www.adlnet.gov/tla/experience-api/

A TAXONOMY OF EDUCATION STANDARDS

The vertical dimension in the matrix represents a taxonomy of standards related to educational efforts. There are three types: Academic Standards, Data Standards and Technology Standards. The taxonomy itself is represented in Figure 23.

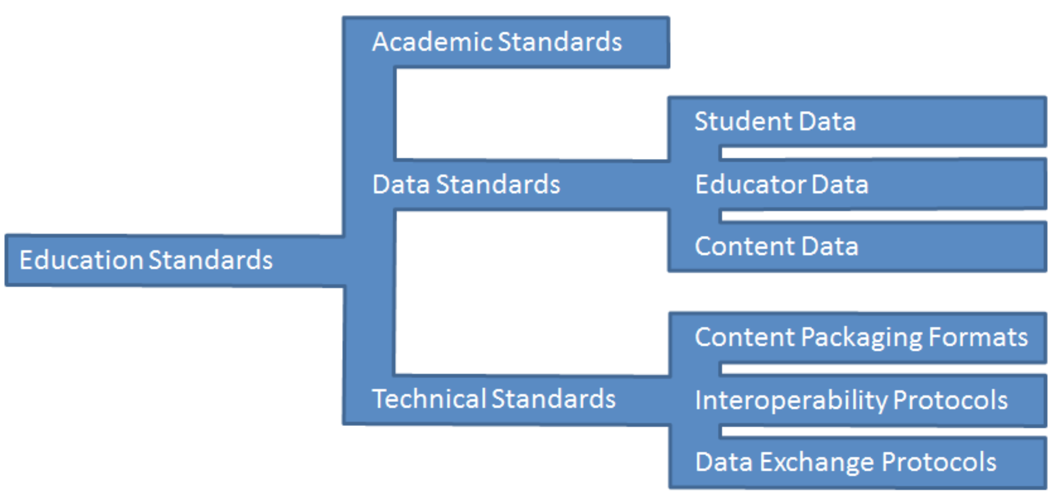

Figure 23. A Taxonomy of Education Standards

Academic Standards include achievement standards like the Common Core State Standards (CCSS)[1], the Next Generation Science Standards[2], and other state and national standards. Contemporary practice in the U.S. involves describing achievement standards in the form of learning objectives - descriptions of skills that students can acquire or demonstrate.

Historically, and in higher education, it is more common to describe such standards in syllabus form, as a list of topics to be studied. Some higher education institutions have developed their own sets of standards, but most leave the learning objectives up to the professor. A few industry organizations publish standard sets. These include the AAAS Benchmarks for Science Literacy[3] and the National Center for History in the Schools standards.[4]

Academic standards also include knowledge taxonomies like the Library of Congress Classification[5] or the Dewey Decimal Classification. They include measures of text complexity such as the Lexile[6] scale. And they include other classifications like Bloom's Taxonomy[7] and Webb's Depth of Knowledge scale.[8]

Data Standards define the data elements and structures used to store and exchange educational information. For education, the three major domains of data standards are Student Data, Educator Data and Content Data. Important metrics like graduation rate, student financial aid repayment or college-matriculation rate are typically derived from these data sets.

Student Data includes traditional demographic information as well as a student record that includes academic achievements, assessment results, learning activities, attendance and so forth.
Educator Data includes information about teachers and staff. It includes qualifying information like academic credentials, a portfolio of creative works, and publications and data about teaching performance.
Content Data, often called metadata, is information about learning materials including textbooks, assessments, multimedia and digital resources. Content data often indicates the alignment between learning resources and academic standards they are developed to address.

Technical Standards define how systems interoperate. A wide variety of standards may fit into this category, but the majority of education-related technical standards involve Content Packaging Formats, Interoperability Protocols and Data Exchange Protocols.

Content Packaging Formats support the transport of learning content (e.g., text, video, graphics, etc.) and assessment content between systems.

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2. Next Generation Science Standards. http://www.nextgenscience.org
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Interoperability Protocols support interoperability among learning systems. The most common use case for interoperability protocols is integration of rich learning tools (like simulations, games or assessments) into learning environments (like a learning management system).

Data Exchange Protocols data exchange protocols are usually paired with a corresponding data standard.

THE FOUR LAYER FRAMEWORK FOR DATA STANDARDS

The horizontal dimension in the matrix is drawn from the Four Layer Framework for Data Standards[9]. These four layers describe distinct efforts that are involved in the organization, storage and transmission of data. Any data standard will address one or more of these layers.

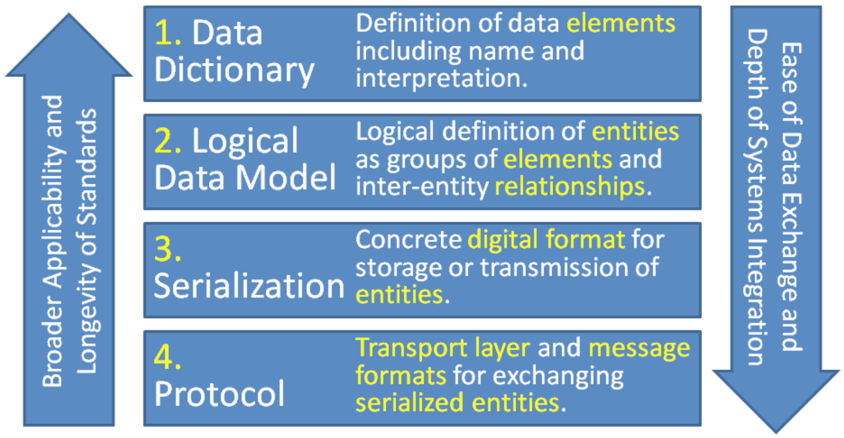


Figure 24. The Four-Layer Framework for Data Standards

The four layers in the framework are the following:

1. The **Data Dictionary** is a list of data elements each with a name, definition and sometimes a format. For example: Name: Birth Date; Definition: day the individual was born; Format: year-month-day.
2. A **Logical Data Model** defines entities as collections of data elements. For example, a logical data model might describe a "student" as having the data elements: first name, last name, birth date, gender, address, etc. This collection of elements (defined in the data dictionary) is a student entity or record. The data model also defines relationships between entities, and those relationships have names. For example, a "registration" might be the relationship between a student entity and a class entity.
3. A **Serialization** describes in detail how the data, from a logical data model, is represented on a computer for storage or transmission. CSV[10], XML[11] and JSON[12] are commonly used frameworks for serialization. CSV works well for tabular data like you might find in a spreadsheet. XML and JSON are hierarchical in nature. Custom serialization formats are also common. Terms synonymous with "serialization" include "physical data model," "binary format," "binding," and "encoding."
4. A **Protocol** describes the way systems communicate to exchange data with each other. This involves establishing contact, transmitting the data, validating that the data are correct and sending acknowledgements.

9. "A Four-Layer Framework for Data Standards." http://x.ofthat.com/papers/fourlayer.pdf
10. Definition: "Comma-separated values (CSV)." Wikipedia.org. https://en.wikipedia.org/wiki/Comma-separated_values
11. Extensible Markup Language (XML). w3.org. http://www.w3.org/XML/
12. JavaScript Object Notation (JSON). tools.ietf.org. https://tools.ietf.org/html/rfc7159

To illustrate how these layers fit together, let's use the example of a shopping list. The data dictionary would identify and define elements like the name of a product to be purchased, the quantity and an expected price. The logical data model would indicate that the element's name, quantity and expected price should be grouped together into an item entity and that the whole shopping list is a list of items. The serialization would indicate that the list is to be inscribed on a piece of paper with three columns, name, quantity and expected price, with one line for each item to be purchased. Finally, the protocol would entail giving the list to your spouse or friend, asking them to go make the purchases and waiting until they have agreed to do the task. If acknowledgement hasn't returned within 10 seconds, then repeat the request.

When all four layers are defined, you achieve plug compatibility; two systems can communicate with simple configuration settings. However, it can be challenging to define all four layers at a sufficient level of detail. And that degree of definition can constrain product innovation. Because of this, standards that just address layers 1 or 2 have broader applicability. Even without plug compatibility, the task of integrating two systems is greatly simplified by agreement at the data dictionary and logical data model layers.

EXAMPLES AND APPLICATIONS

For a specification to be a standard, it must be governed by a standards body that organizes the effort of writing the standards, facilitates review and approval, and advocates for applications of the standards. The respective groups frequently collaborate to ensure that complementary standards work together or build upon each other.
Here are some examples of how standards relate to each other and how they have been applied.

CEDS, A4L, and PESC

The team behind the Common Education Data Standards[13] (CEDS) deliberately chose to concentrate on layers 1 and 2 –Data Dictionary and Logical Data Model. This has resulted in CEDS being adopted broadly in the community. However, a complete solution must address all four layers. During the development of CEDS, A4L[14] and PESC[15] contributed their data elements and models for K-12 and postsecondary education respectively, and they continue to participate in the CEDS effort. Meanwhile, the SIF standard (managed by A4L) and PESC standards incorporate layers 3 and 4 while maintaining alignment to CEDS data elements. Thus, the combined standards offer an aligned four-layer solution.

IMS CC and LTI

IMS Global[16] is a standards organization focused on digital learning content including curriculum and assessments. Two of their standards, Common Cartridge (CC) and Learning Tools Interoperability (LTI), address how to incorporate published learning materials into a learning management system. The two standards approach this challenge in distinct ways.

13. Common Education Data Standards. http://ceds.ed.gov
14. The Access for Learning Community (A4L) (formerly the SIF association). http://www.a4l.org
15. The P20W Education Standards Council (PESC). http://www.pesc.org
16. IMS Global Learning Consortium. http://www.imsglobal.org

Common Cartridge is a packaging format for learning materials. A developer or publisher of learning materials can package them up in CC format for distribution. On the receiving end, the package is loaded into a learning management system for delivery to students.

LTI is a protocol for communication between a learning management system and a learning tool hosted on a separate website. Through LTI, a student using a learning management system can access a sophisticated learning tool or library that's hosted on a different website but seamlessly integrated into their learning experience. Bringing it full circle, Common Cartridge can also be used to package links to LTI learning materials.

So, Common Cartridge and LTI are a packaging format and a protocol for accomplishing similar goals – each with distinct advantages.

LRMI and the Learning Registry

The Learning Registry is a protocol for exchanging descriptive information, or metadata, about learning resources. Client applications connected to the learning registry facilitate students and educators searching the learning registry to find relevant learning materials.

The Learning Resource Metadata Initiative defines standard metadata for describing learning materials including how materials are aligned to educational standards. The two initiatives work well together. Metadata, in LRMI format, is transmitted and exchanged using the Learning Registry protocols.

xAPI and Caliper

Any competency education effort must measure student achievement. The traditional evidence of student competency comes in the form of response to assessment. However, evidence also comes from observing student activities. And data about student activity can inform improvements to the learning materials.

The Experience API (xAPI) and IMS **Caliper Analytics™** are two protocols for gathering records of student activities. Where an assessment would collect the student's response, xAPI or Caliper would record what materials a student viewed, how much time they spent on a task, how they manipulated an assessment, where they clicked on the screen, in addition to many other activities both online and in the real world.

STANDARDS IN THE SERVICE OF STUDENT LEARNING

Personalized learning occurs at the intersection of student data, content data, and achievement standards. Student data indicates where the student is in a learning progression, achievement standards indicate what is to be learned next, and content data indicates what learning content can help the student achieve the next step. Each of the standards efforts in the learning matrix contributes in some important way to the overall goal of more effective student learning.

Appendix B: Data and Application Design for a Student-Centered Learning Integrated System

CONCEPTUAL DESIGN OF A STUDENT-CENTERED LEARNING INTEGRATED SYSTEM

The following pages detail the concepts involved in the design of a data and application architecture for a student-centered learning integrated system presented in the main paper. The architecture integrates various functions of technology to address the needs of learners, educators, parents/families, administrators and other stakeholders in support of student-centered learning. This architecture is built on the assumptions of the following design principles for student-centered learning:

- **Learning is Personalized:** Personalized learning recognizes that students engage in different ways and in different places. Students benefit from individually paced, targeted learning tasks that formatively assess existing skills and knowledge and address the student's needs and interests.
- **Learning is Competency-Based:** Students move ahead when they have demonstrated mastery of content, not when they've reached a certain birthday or undergone the required hours in a classroom.
- **Learning Happens Anytime, Anywhere:** Learning takes place beyond the traditional school day—and even the school year. The school's walls are permeable; learning is not restricted to the classroom.
- **Students Take Ownership Over Their Learning:** Student-centered learning engages students in their own success and incorporates their interests and skills into the learning process. Students support each other's progress and celebrate success.

Student-centered learning is different than teacher-centric instruction since it focuses on the individual student and the instructional processes to support a student-centric learning cycle. The core functions and processes that the student-centered learning integrated system (SCL IS) must support are learner-centric instead of teacher- or group-centric. At the core of this system design sits the individual learner's learning experiences and interactions with peers, educators and others involved in the education of the learner and learning resources, how these experiences and interactions are supported and assessed and the ways in which the data and reports from these are used to inform practice .

Architecture Designed to Support Student-Centered Processes

This data and application design is guided by what learning scientists and cognitive science researchers have discovered about how people learn, how people make sense of new concepts and how novices become experts. Many of the discoveries about how the human brain develops have been difficult to apply within traditional teacher- and group-centric instructional models. Those same discoveries can and are being applied within technology-enabled models of student-centered learning.

The processes of student-centered learning and the data that are most critical to support student-centered learning are different from the processes and data used to support traditional classroom models, school operations, and accountability. Some data that are critical for school administration, school accountability, legal compliance, and answering policy questions are not the just-in-time, individual learner specific type of data used to support the processes at the core of student-centered learning. Instead, data such as the detailed transactions of learner choices and learning experiences, formative feedback, and progression within a competency framework are more valuable in supporting student-centered processes.

The primary design objective of student-centered learning is to optimize learning for each student. Therefore, one of the most critical functions of the SCL IS is to enable personalized learning experiences, which may be through the learner's direct interaction with a teacher, a component of the system, with content delivered by the system or as a combination of online and offline experiences. Whether the experience takes place online or offline, the SCL IS must facilitate the provision of learning experiences based on individual student strengths, needs, interests and motivations, providing meaningful, timely feedback to the learner from multiple sources in a student-centric interface.

An additional focus of student-centered learning centers on facilitating student ownership of learning by engaging students in co-planning their learning, incorporating their interests and skills into the learning process, monitoring their progression and celebrating their own successes. They have a clear understanding of what they have mastered, set goals for what they need to know and be able to do long-range, know what they need to master short-term to reach their long-term goals and receive frequent feedback on their progress. They use data to diagnose, direct and drive their learning. They have multiple opportunities to direct, reflect and improve on their own learning through formative assessments and data reports that help them understand their own strengths and learning challenges. Students take increasing responsibility for their own learning, using strategies for self-regulation and reflection. Students support one another's progress and celebrate success.

A number of things differentiate a student-centered instructional cycle from a traditional instructional cycle.

- The student is the center of learning. A learning team of partners that includes the teachers, peers, parents and others involved in the student's education and well-being supports learning.
- Learning is co-planned by the student and teacher and may involve others in the planning. During the co-planning process, the student, teacher and others involved in the planning process use data, including data in the Student Learning Profile, to review what the student knows and needs to know, as well as what the student wants to learn beyond the required outcomes. The team discusses the resulting personalized goals, competencies, and learning targets, how the student learns best, and the student's interests. It uses this information to determine how the student will demonstrate his/her learning. The locus of control for learning is shared between the student and teachers; and it progressively moves more toward the student as he or she increasingly takes ownership and responsibility for his or her own learning.
- Learning is based on the individual student's goals, progress on mastery of clearly defined competencies, needs and strengths, interests and motivations. From this co-planning process, a personalized learning plan (PLP) that includes goals, competencies, learning targets, instructional approaches and selected ways to demonstrate learning is developed. After developing the personalized learning plan (PLP), the learning team selects the resources (digital and human) that will be incorporated into the PLP or a playlist-type function.
- The learning cycle includes ongoing feedback based on multiple measures of student progression towards attaining clearly defined learning targets and competencies.

» The learning cycle is continuous. If a student does not demonstrate mastery, the learning team analyzes the data and revises the selection and use of instructional approaches, ways to demonstrate learning, selection and assignment of resources (digital and human), feedback strategies and intervals during learning, and perhaps the assessment measures and strategies. If a student does demonstrate mastery, the student and teacher may decide that the student will move on or explore the concepts related to the competency in more depth.

The central elements described here form a logical relationship for student-centered learning, as represented in Figure 25 below.

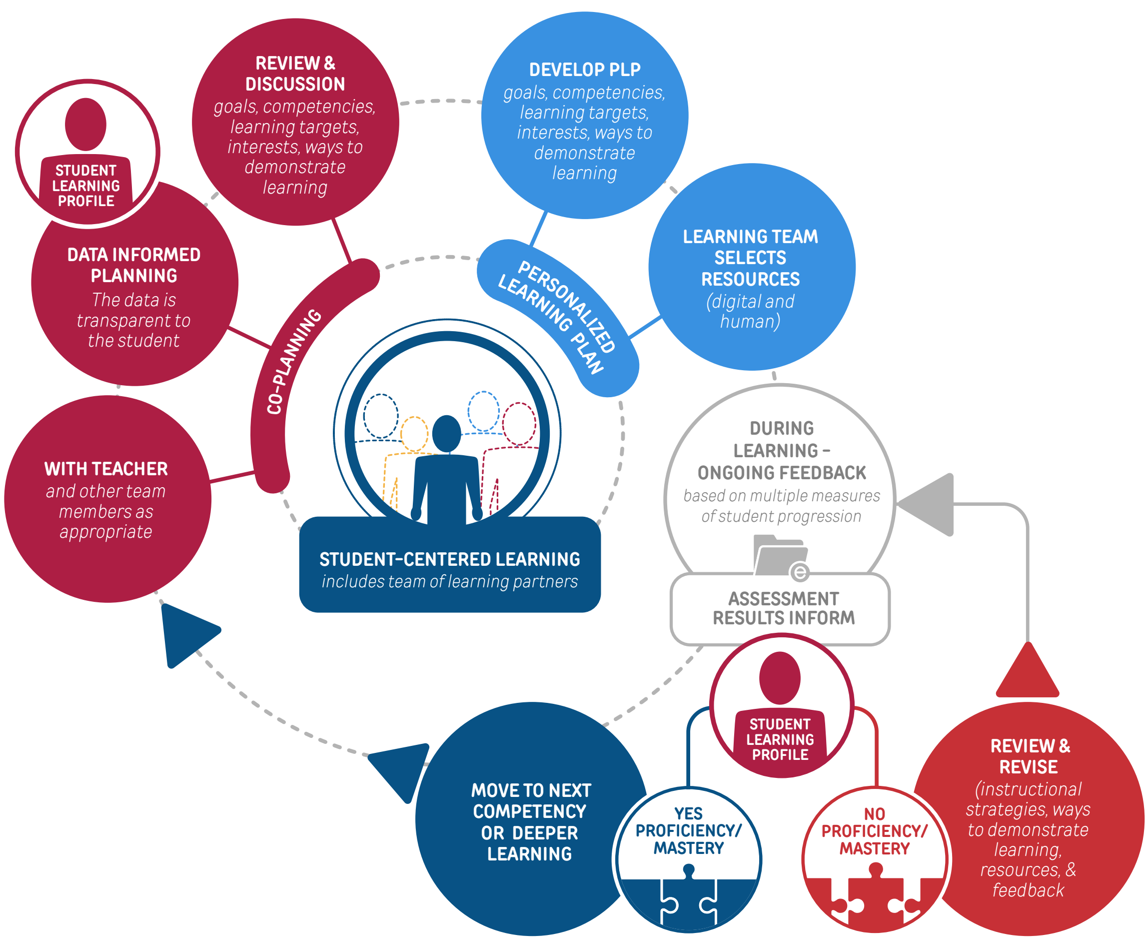


Figure 25. Logical Relationship for Student-Centered Learning

This instructional cycle for student-centered learning serves as the foundation for understanding the information systems needed to support that cycle.

Modular Architecture

Supporting student-centered learning requires multiple systems that work together to enable the desired learning ecosystem. The system must support a complicated set of processes and functionality that make up personalized and competency-based learning, anytime, anywhere learning in multiple settings and varying periods of time plus student ownership. Therefore, this technical design is modular and based on the integration of multiple technologies. The following core considerations are essential to a well-designed student-centered learning integrated system:

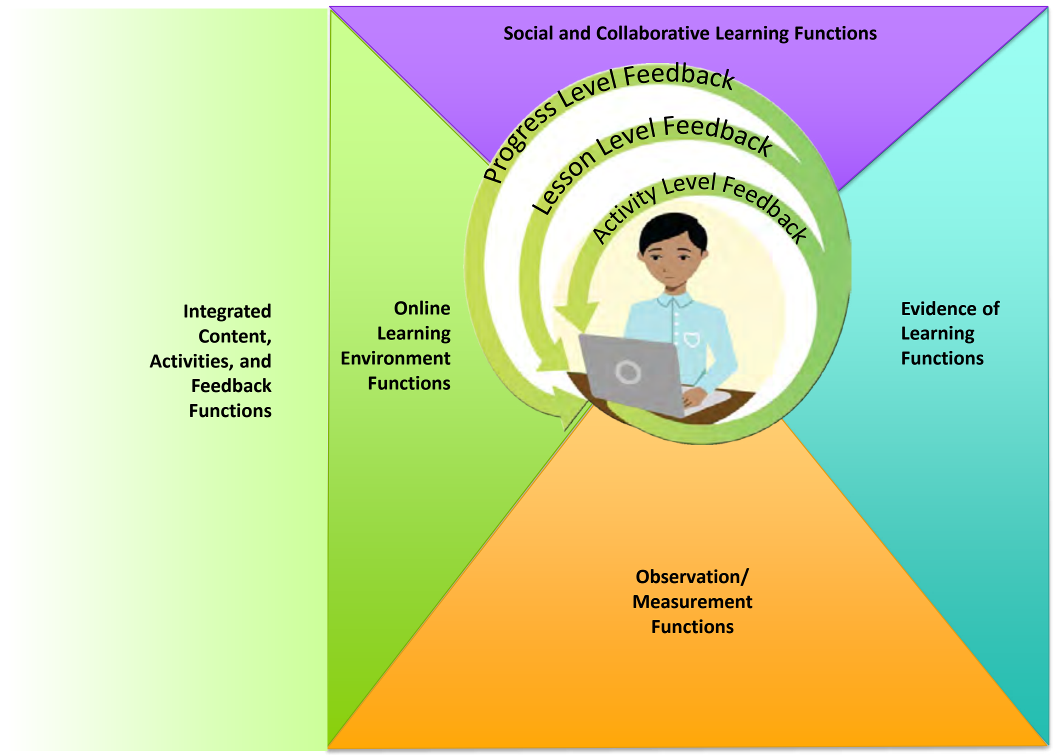
- A reference framework for aligning learning experiences, resources, assessment and reporting to the competencies
- Customized learner profiles that combine data from source systems and input from students, parent, educators and others involved in the student's education and well-being
- Personalized learning plans that are responsive to the learner as the learner progresses and changes
- A variety of learning experiences within and beyond the school setting and calendar and the collection of the associated data to inform student progress
- Access to content, digital resources, human resources and tools through a user-centric interface
- Meaningful, timely feedback during the learning process
- Multiple ways of demonstrating and assessing mastery towards competency
- Relationships, collaboration and communication
- Dashboards that show in real time which concepts and objectives students have trouble with, pinpoint at-risk students and enable targeted intervention
- Analytic tools to support data-informed practices (learning, teaching, administration)
- Integration of multiple systems and data flows using data and interoperability standards and practices

The software, services and learning content needed to support student-centered learning must be distributed. The SCL IS must be flexible and draw on best-in-the-world resources and technology. In this design, the functions may be provided by different enabling technologies and will require the integration of the different teaching, learning and business system applications. Using consistent data standards and establishing interoperability between these applications will enable data to flow more seamlessly.

Standards are critical, especially at the points in which separate systems need to integrate and the data from those systems need to interoperate. Numerous data and technical standards exist within the educational space to support interoperability. In Appendix A: Understanding Education Technology Standards, Brandt Redd presents a model for understanding education data standards and technical standards. In this appendix, we will go in-depth while discussing the standards as they relate to each of the points of intersection within this design after presenting the holistic design. These points of integration are numbered in the figures that follow.

We've organized the system functionality into these key functional components. Each of these key functional components represent high-level functions and include a variety of subsystems.

- Online Learning Environment Functions
- Integrated Content, Activities, and Feedback Functions that the learner will access through the Online Learning Environment
- Observation and Measurement Functions
- Evidence of Learning Functions, and
- Social and Collaborative Learning Functions



Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 26. Key Functional Components

This student-centric core is supported by other system components (discussed in the main paper) that are removed from the direct learning experience, but serve in critical supporting roles, such as managing learning resources, providing educator interfaces and maintaining the security of personal data. These capabilities are included in the Conceptual Framework: District Core Capabilities for Student-Centered Learning (pages 32-37). As critical as these components are, the primary goal is to facilitate and optimize student progression through personalized learning experiences. That is where this technical design begins.

THE ITERATIVE LEARNING PROCESS

Whether learning to talk, read, play a game or apply the Pythagorean theorem to a real-world problem, learning is an iterative process that requires feedback. The process starts with a baseline understanding of the context (e.g., before learning to talk, a baby understands that sounds can convey meaning). That baseline understanding is expanded through observation or experience, such as a baby hearing her mother say words and seeing her lips move (e.g., "Say Mama!").

During this observation or experience, the learner could be passive, such as a student during a lecture or a baby observing what others around him are doing. Or the learner could be active, such as a student using a physics simulation or a toddler learning that a stove is hot (the hard way). In some cases, like the toddler approaching the high-temperature stove or a well-designed simulation, immediate feedback occurs that allows the learner to correct, improve, or validate performance or understanding. When learning experiences are more passive in nature, such as listening to or viewing a lecture or reading with no embedded checks for understanding, a subsequent assignment could be used to assess the learner's level of understanding for each applicable learning objective and feedback provided.

Student action followed by feedback is essential to the student-centered model and is a critical design feature of the SCL IS. For the purposes of the SCL IS design, we broadly define feedback to include any information provided to the learner that helps correct misunderstanding, reinforce or extend learning or indicate what the learner should do next. Sometimes the feedback comes from a teacher or tutor. Sometimes the feedback loop entails the learner recognizing an error and self-correcting or reflecting upon his learning. It could be that the learner has a complete or partial lack of understanding of prerequisite concepts and the feedback directs the learner back to learn the prerequisites, it could be that the learner has a misunderstanding and the feedback provides the information needed to correct misunderstandings, or it could be that the learning objective has been mastered and the feedback says to move on or explore the concepts in more depth. Technology can greatly enhance feedback loops for learning.

"**Feedback** is information provided by an agent (e.g., teacher, peer, book, parent, self, experience, software) regarding aspects of one's performance or understanding."

///

– Definition adapted from "The Power of Feedback" by John Hattie and Helen Timperley (2007)

The technical design assumes that feedback is provided on multiple levels:

1. **Activity level –** Formative feedback during a learning experience
2. **Lesson level –** Feedback after a learning experience that checks for understanding
3. **Progress level –** Feedback on where a student is in relation to learning objectives and competencies, district and state interim and summative assessments, and other measures of progress.

Feedback requires observation or measurement. For example, when a baby points to a picture of a cow and says, "dog," the parent observes the misunderstanding (the child's misunderstanding that everything on four legs is a dog) and provides the corrective feedback, "cow." In formal educational contexts, measurement often must be more formal (assessments instruments, scoring rubrics, etc.) in order to support feedback.

Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 27. Feedback Levels

The kinds of instruments used to measure and provide feedback are an important design consideration. Many assessment items/instruments, especially summative assessments, do not measure at a suitable level of granularity to identify specific misunderstandings or skill deficiencies. The observation or measurement must be suitable to support the intended level of feedback. For example, at the activity level, the observation/measurement involves what the learner is doing right now. The feedback may be in response to a specific learner action related to a single learning objective. Feedback given immediately following the observation/measurement may include prompts or questions that help the learner self-correct misunderstandings within the context of the learning activity.

Lesson level feedback, on the other hand, may be based on multiple measures, sometimes for multiple related learning objectives, to assess how well a student has learned something. The lesson level measurements may include aggregate analysis of activity level measurements and "exit ticket" assessments given at the end of a lesson in order to determine whether the student is ready to move on—or whether additional activities addressing a learning objective should be prescribed.

Progress level feedback provides the student with information as to where he or she is in relation to his or her learning objectives, goals, and district and state assessments. It helps the student and learning team determine where to start and what to do next.

Timely, meaningful feedback and the ability to act upon the data provided through feedback prove essential to student-centered learning. Data enables students and educators to make informed judgments about what students have learned, how well they've learned it, what to learn next, as well as effective strategies and resources.

INTEGRATED STUDENT-CENTERED LEARNING SYSTEM FUNCTIONAL COMPONENTS

In this section, we will build the design by discussing each of the functional components of the SCL IS and showing the points of integration.

The Online Learning Environment Functions and the Associated Integrated Content, Activities, and Feedback Functions

The online learning environment is the student's personal online workspace, providing a single sign-on, student-centric user interface. In this personal workspace, the student has access to all the tools, content, assessments, and data needed to support the learning process. The online learning environment provides the context from which the learning experience is delivered, and students take ownership of their learning. All other components of the SCL IS that a student needs to use are accessed through this portal. This requires standards-based approaches to single sign-on and content/tools integration.

The online learning environment needs some information from the district's source systems (integration point 1) to roster students and staff. Generally, this data comes from the Student Information System, Human Resources or other systems that record which course sections the student is enrolled in and which teachers are assigned to those classes. Some SIS systems are evolving to enable student assignments consisting of more than one teacher within a content sequence that expands more than one calendar year.

Figure 28. Online Learning Environment Supports User Interface and Source System Integration

The Online Learning Environment is one function of systems that traditionally falls into the learning management system (LMS) category. Many LMSs, however, do not meet the design requirements for student-centered learning since they were designed to support teacher-centered, course-centric learning processes rather than student-centered processes. This design focuses on LMS features needed to meet the functional requirements for student-centered learning.

Learning Experience Functions

No single system or source has the rich set of learning experiences or content needed to deliver personalized learning at scale. The SCL IS must support both online and offline activities, therefore, there will be multiple sources of learning activities and content. The integration of learning activities and content is a critical component of systems integration. Online activities could range from adaptive, content applications that provide instruction targeted at the needs of the student, to hosted software like a learning game (*Lure of the Labyrinth*), to static content such as text or videos, to collections like *Khan Academy*, to online courses. No matter what it is, the activity needs to integrate into the learning environment. The SCL IS makes it look like the content or software is built in, when in fact it may be hosted on another server. Each learning experience includes online touch points that provide an opportunity to collect valuable data to inform teaching and learning.

The use of the SCL IS to support offline activities may mean that the system provides instructions for the learner to follow during an offline activity, online tools for completing and submitting the activity and assessments to measure learning and give feedback. Tools to support project-based learning (planning, project management, reflection) would be accessed through this workspace.

An offline, project-based learning activity may be designed with any number of online touch points. Edutopia suggests Five Keys to Rigorous Project-Based Learning:

» Establishing Real-World Connections in Projects
» Building Rigorous Projects That Are Core to Learning (aligned to learning standards)
» Structuring Collaboration for Student Success
» Facilitating Learning in a Student-Driven Environment
» Embedding Assessment Throughout the Project

Each of these key elements can be supported through online interaction and collaboration, content, assessment, and evaluation tools.

The SCL IS must support learning as a series of logically connected experiences/activities. It facilitates the connection between the discrete experiences on the front end through the personalized workspace, but depends on a number of behind-the-scenes systems that deliver content and experiences and link them to competencies. Competency education requires systems that align learning resources and other data to competencies.

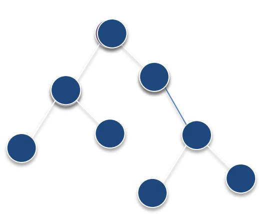


Figure 29. Reference Framework

Reference Framework

Student-centered learning is competency-based. So it is important that learning activities, content and assessments are linked to specific competencies. For that we need a component with information about the competency framework. In this design, we call that information model a reference framework. The reference framework functionality can support all kinds of educational frameworks, not just competencies, for example Bloom's taxonomy levels or Lexile ranges. The reference framework defines what a learner should know or be able to do and defines rules for measures that indicate levels of mastery.

The reference framework will often be based on learning standards adopted by the jurisdiction (e.g., state or local school district). It may also include standards for habits of learning and indicators for 21st Century skills. It may include additional information about how to measure levels of mastery, more granular competencies (such as process steps that make up a skill) and relationships between individual competencies (e.g., prerequisite/post-requisite relationships). While competencies can be related to courses, competencies are not courses. Reference frameworks are typically defined as a hierarchy of statements with the subject matter context at the top (e.g., Mathematics), one or more levels of classifying statements (e.g., Number and Operations), and one or more levels of competency definitions. They may include recommended and alternative competency pathways.

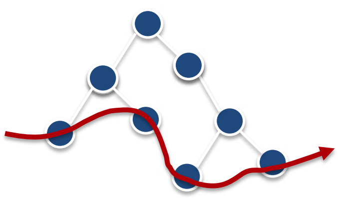


Figure 30. Pathway in a Reference Framework

Competency pathways show recommended or prescribed pathways for student learning, such as what competencies to address before, during or after addressing what other competencies. These pathways are defined as a set of associations between nodes in the framework. There can be one recommended pathway or multiple recommended pathways to address multiple learner profiles.

For example, the Dynamic Learning Maps project has defined frameworks that include competency pathways for students with significant cognitive disabilities, and alternative pathways defined for different disability types. (http://dynamiclearningmaps.org/)

Competencies in a Reference Framework can be a component of a course or content band, and competencies can span courses or content bands. See Glowa, Re-Engineering Information Technology: Design Considerations for Competency Education, February 2013, http://www.inacol.org/resource/re-engineering-information-technology-design-considerations-for-competency-education/ for a more thorough discussion of this. Courses or content bands and competencies can have a many-to-many relationship.

Learning activities and content are linked to specific competencies (and other taxonomies) through the Reference Framework. The taxonomies in the frameworks also provide the basis for reporting, analytics and learning resource discovery. Learning activities and content linked with competencies in the Reference Framework are accessed through the Online Learning Environment, as represented by integration points 2 and 3 in Figure 31.

The SCL IS must include systems that store information about competencies in machine-readable and human-readable formats. Data standards exist for encoding and storing reference competency frameworks in machine-readable form and for using these standards framework in models for competency-based pathways. The data standards provide a flexible structure that supports any number of levels of granularity.

Learning Resource Discovery

Learners and teachers also need a way to discover learning resources. This function is provided through a learning resource discovery component. This could be a search engine that draws from a curated list of resources and filters based on the current learning objectives. Users could then further refine their search based on learning preferences, ratings and other metadata.

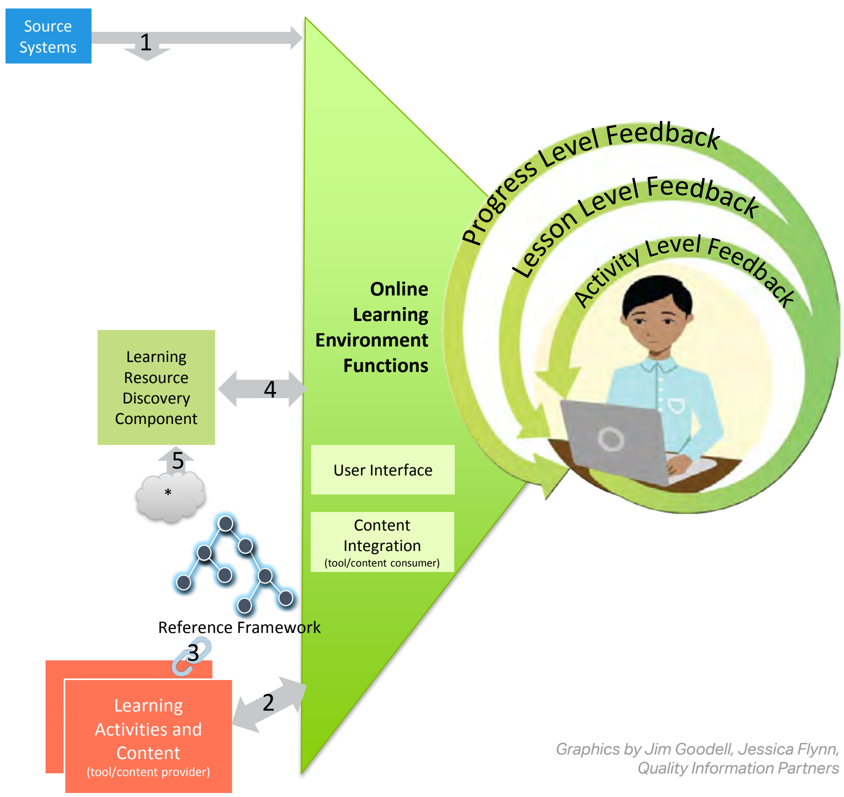


Figure 31. Reference Framework and Learning Resource Discovery

The SCL IS supports the discovery of a rich variety of learning resources and activities. Unlike teacher-centric models, which provide a fixed lesson plan with the same set of activities for all or groups of learners, the SCL IS provides multiple options to meet each learner's needs and preferences. A system that supports student-centered learning should allow students to choose from a set of curated activities and resources in pursuit of a learning objective.

Digital content, for example the curated activities and resources, is often stored in specific digital libraries, called Learning Object Repositories (LORs). Currently there is a significant growth of LORs as part of the hidden Web in large databases. These systems typically provide a Web interface to allow the searching of education resources through the metadata. A system may include a LOR managed by the institution for institutionally developed resources, commercial LOR products and Open Education Resources LORs. The ability to do intelligent searches of these LORs using a single search engine is provided through the learning resource discovery component. This is integration point 4.

The learning resource discovery technology provides the back end functionality to grant learners access to the right selection of resources. This does not mean that the student should be overwhelmed with too many choices at once, but it does mean that multiple resources are offered representing various learning preferences such as video, text, simulations, projects, etc.

For learning resource discovery, the system contains the following subsystems, at a minimum:

» A data store containing learning resource metadata including alignment of resources to competencies (i.e., aligned to a reference framework).
» A search engine or recommendation engine for narrowing down the choices.

The learning resource discovery system may be: 1) used by an educator to curate a limited number activities assigned or offered to the student at a point in a personal learning pathway, 2) used by the student to discover resources/activities applicable to the learning objective or interest, or 3) a school, district or state to created curated collections for staff, students, and parents..

> ***"In the future—much as with Google or Amazon where the user has a lot of control but the engine is also automating and making suggestions to enhance that control—you're going to see similar marriages in learning."***
>
> *Michael Horn (http://evolllution.com/programming/teaching-and-learning/improved-analytics-critical-personalization-online-learning/)*

The metadata repository may be self-contained or integrate with other sources of learning resource metadata, such as a Learning Registry node. This is integration point 5.

The Learning Registry

The Learning Registry is a Web-based catalog of learning resource information and an infrastructure for sharing information about learning resources across organizations. The Learning Registry helps address the problem of resource quality by providing a protocol for vetting resources. It allows persons and organizations to make assertions about the quality of resources, alignment to standards or applicability to types of learner needs and preferences. Another organization may set up its learning resource discovery system to consume the information about resources only from trusted organizations or based on other filter criteria. The Learning Registry uses the set of metadata tags defined by LRMI.

Assignment/Activity Lists

Another component provides assignments and "playlists" for the student. The processes for the personalization of these lists will be discussed throughout the other functional areas. Whether the assignment/activity is a discovered resource, a teacher assigned learning activity or a student developed activity, it needs to link to the Reference Framework for information about the competencies and other frameworks that the district may have included, such as Depth of Knowledge level or text complexity.

Learning Maps

Learning maps help learners see the bigger picture. The institution will need to define what it wants the learning map to include and display. There are different kinds of "maps" in various commercial products such as competency maps showing where the student is and where the student is going. *Khan Academy* has a map visualization showing recommended paths through math competencies. The learning map is not the student's personalized learning plan but is used to inform the PLP.

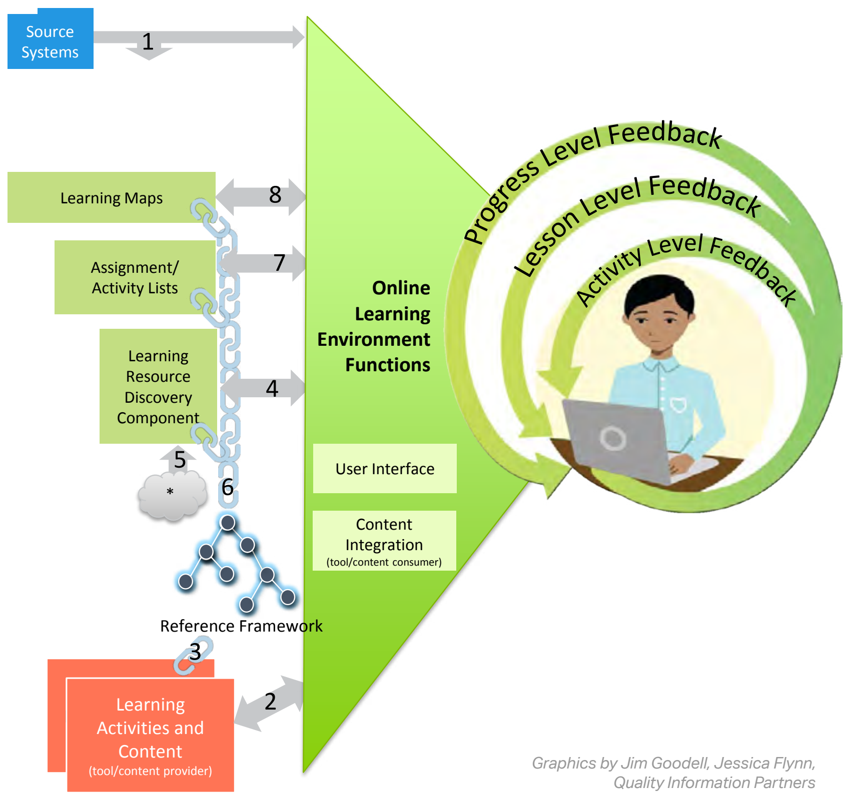
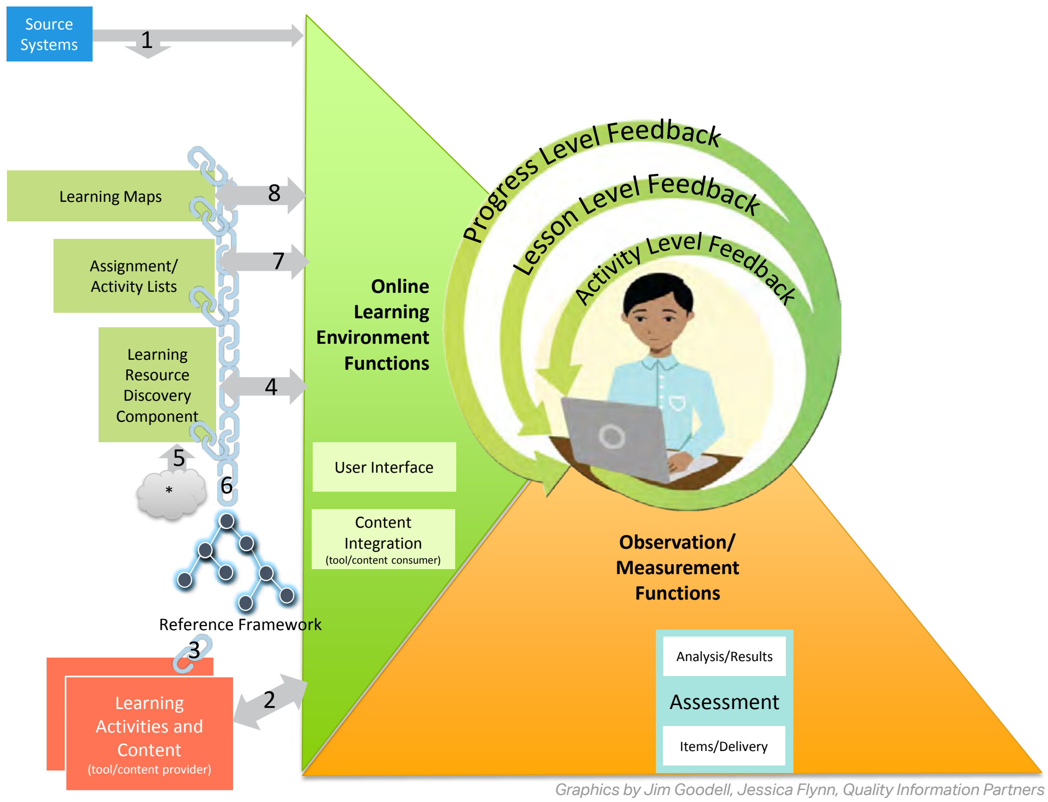


Figure 32. Assignment/Activity List and Learning Maps

Content referenced within Assignments/Activities Lists and Learning Maps link to relevant nodes within a Reference Framework. This is integration point 6 in Figure.

Assignments/Activities Lists and Learning Maps are made available within the Online Learning Environment as represented by integration points 7 and 8 in Figure. 32



Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 33. Observation/Measurement Functions

Observation/Measurement Functions and the Associated Integrated Content, Activities, and Feedback Functions

Earlier, the iterative nature of the learning process was described as a continuous cycle of experience – feedback – experience – feedback. To support the right kind of feedback, the SCL IS must track, store and report information about where the learner stands in relation to the learning objectives and update the learner model in real time. *"The learner [specific] model is a model of the knowledge, difficulties and misconceptions of the individual. As a student learns the target material, the data in the learner [specific] model about their understanding is updated…"* (Bull, 2004)

Graphics by Jim Goodell, Jessica Flynn, Quality Information Partners

Figure 34. Feedback Levels

Systems for Learner Feedback and Guidance

The SCL IS components need to provide feedback to the learner at different levels within the learning process, from different sources such as educators, peers or intelligent algorithms (such as tutoring systems or recommendation engines). Feedback is also included in the processes that support learner motivation and ownership. The SCL IS components empower learners to support each other's progress and to celebrate success. As described previously, feedback is provided on multiple levels: activity, lesson, and progress. Data dashboards (visual representations of student progress in relationship to learning maps) are often used to display progress-level feedback and learner profiles.

Activity Level Feedback System

Activity level feedback takes place during the learner's interaction with a learning resource. This level of feedback may be embedded within the digital learning resource, such as an assessment-as-learning system that immediately informs the learner of a wrong answer and remediates with a scaffolding question or series of hints. Activity level feedback is embedded within the assessment item content, and the delivery of feedback is a function of the formative assessment platform. This kind of feedback mirrors the kind of feedback offered by a good tutor during a one-to-one tutoring session. Another example of activity level feedback is game-based learning experiences that respond instantly to learner actions or provide "heads-up displays" showing indicators related to immediate goals.

Lesson Level Feedback System

Lesson level feedback helps the learner determine what to do next. It is often informed by a post-activity assessment to check for understanding. It may also be informed by other data collected during current and previous activities, competency models and the learner model. For this reason, lesson level feedback is a component that needs to interface with other components of the SCL IS. Adaptive learning technology integrates a recommendation engine, personal workspace and dashboard for lesson level feedback. The technology adjusts the instructional plan for the student, such as what instructional content the system will offer next. For example, *Khan Academy* will use assessment practice to adjust recommendations; D2L's *LeaP* will populate a list of content options based on data.

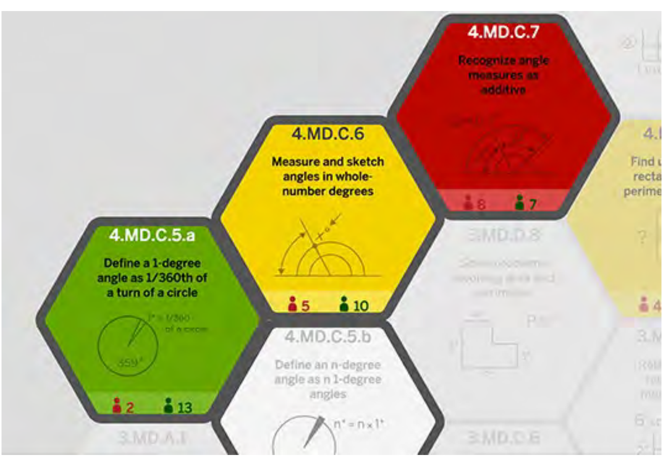


Figure 35. Example of Progress Feedback (Amplify(r) mCLASS)

Progress Level Feedback System

Progress level feedback is primarily designed to answer the question, "Where am I in relation to my learning objectives?" It can also answer the question, "Where am I in relation to district and state assessment expectations?" "What do I do next?" Data dashboards (visual representations of student progress in relationship to learning maps) are often used to display progress-level feedback.

Progress-level feedback may come in the form of a visual map showing learning objectives and the learner's status.

Reference Frameworks and the Learner specific Model

The Learner Specific Model is a model of the knowledge, difficulties and misconceptions of the individual. This is not about a score, but about where the learner stands in relation to the learning objectives. The SCL IS needs a place to store any and all "learner profile" data such as preferences, specific misconceptions, habitual mistakes or exemplary practices that apply across learning objectives, such as self-agency skills. The learner profile provides additional clues that unlock learner needs, preferences and potential. The content of each student's learner profile could be customized based on student needs, platform data requirements and district/family decisions. Some of the data in the profile can be pulled from source systems and additional data added by students, teacher, parents and others working with the student to support his education. This is the kind of information that informs feedback.

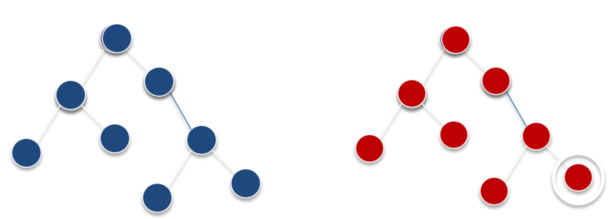
The purpose of the learner specific model is to measure the learner in relation to competencies, not in relation to other students. Some of the data for a learner specific model will come from assessments, but the model is not merely a set of test scores. The model may also include data that help the system or educators determine specific gaps in understanding or performance.

The learner specific model works hand-in-hand with the systems of measurement and feedback, so the assessment data collected within the model must in turn support multiple levels:

- » Identifying specific misconceptions/weaknesses observed during a learning experience. (For example, an intelligent tutoring system that uses scaffolding questions after the learner enters a wrong answer to determine the gaps in understanding that led the student to the wrong answer.)
- » Indicating the level of mastery for each target competency at points in time. (For example, an activity after a lesson checks the learner's understanding of a covered concept or skill.)
- » Displaying progress on a competency-based pathway.

The learner specific model could be designed to support a complex set of data about preferences, specific misconceptions, habitual mistakes or exemplary practices that apply across learning objectives, self-agency skills, etc. We will focus first on learner competency models. The Reference Framework and the Learner Specific Model are two key components in competency education.

As described earlier, the reference framework will often be based on learning standards adopted by the jurisdiction (e.g., state or local school district). It may also include standards for habits of learning and indicators for 21st Century skills. It may include additional information about how to measure levels of mastery, more granular competencies (such as process steps that make up a skill) and relationships between individual competencies (e.g., prerequisite/post-requisite relationships).



Reference Framework **Learner Specific Model**

The learner specific model shows learner progress in an actionable representation of what the learner knows and is able to do in relation to the reference framework. For each node in the reference model, we can assess the learner's level of competency. The learner specific model keeps track of evidence data from measurements, observations and artifacts that are also linked to nodes in the reference framework. It serves as the data store for the learner profile and the achievement tracking function.

One technical approach that proves suitable for competency-based online learning systems is to make the reference framework granular enough that the specific competency can be measured. Often the node in the learner specific model is either "not met" or "met" or specific proficiency levels on a defined proficiency scale. Rules within the system determine which combination of granular sub-nodes needs to be "met" for the higher-level node to be "met." Fine-grained reference models may be too complicated to manage without technology. The system masks complexity by rolling up results to the appropriate level for learners and educators.

Sources of Data

There are multiple sources of data that may be used to inform the learner specific model. These data fall into functions that are served by separate system components:

» assessment data
» experience data
» artifacts of learning

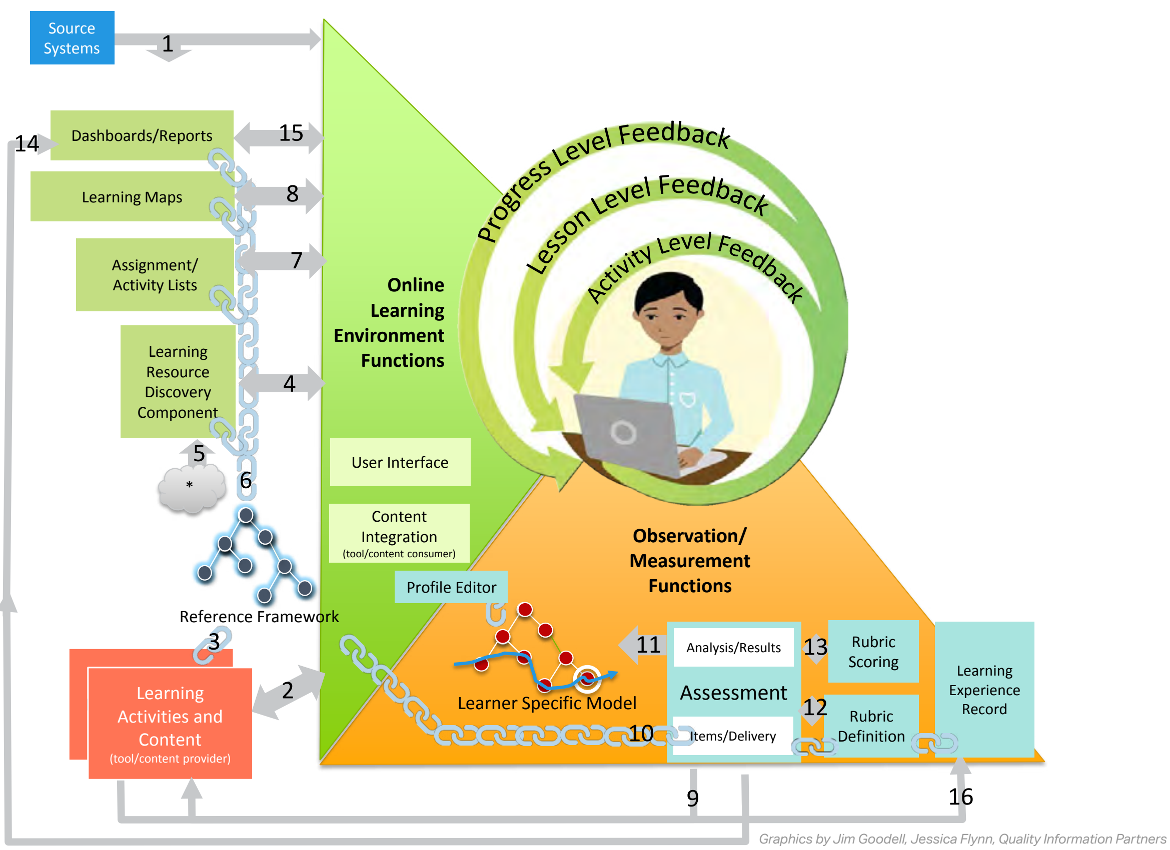


Figure 36. Learner Model and Data Sources

Assessment Data and Systems

The most common and high profile assessment data, from high-stakes assessments, are not the kind of data that are most important for student-centered learning. For competency-based, student-centered learning, we are not concerned as much with an overall score on a test as much as what the test tells us about the student's ability to do something at a point in time. We not only want to know if the student got a problem wrong, but which wrong answer was given and what that wrong answer might tell us about gaps in the competency being measured. We also want data from a variety of assessment tasks.

> ***"It is the feedback information and interpretations from assessments, not the numbers or grades, that matter."***
>
> *(Hattie, J., Timperley, H.; 2007)*

Formal assessment systems can be further broken down into components for item and test authoring, item and test delivery, registration, scoring, analysis and results. To support formative assessment, item banks and assessment results are essential components. Since the system is supporting competency-based learning, every assessment item and task should be linked to one or more nodes in the reference framework, integration point 10 in Figure 36. The SCL IS needs to support packaging assessment items and tasks for delivery through an online assessment system, embedded assessment engine or project-based learning system that is delivered through the Online Learning Environment. It also supports linking assessment results with the delivery of Learning Activities and Content, integration point 13.

Some assessment tasks require rubrics for scoring, so the SCL IS needs to include the ability to host rubric definitions. Furthermore it needs to support linking the results of an assessment to criterion levels within a rubric. This is presented in integration points 12 and 13. The use of rubrics is an important component for project-based learning and portfolios, both of which are aspects of the Evidence of Learning Function.

Rubrics give an opportunity for learners to self-assess and get feedback from peers and educators. If more than one person completes a rubric, a set of multiple measure using this rubric is created. This set of multiple measures can be rolled up to a score or performance evaluation. For example, a different weight could be applied to the results from peers than the result from a teacher evaluation.

There are data standards for rubrics. These are differentiated based on whether the rubric is a holistic or analytic rubric.

EXAMPLES OF HOLISTIC AND ANALYTIC RUBRICS.

Rubric Title	Project Rubric (holistic)
Rubric Description	This rubric is used to evaluate the student's performance on the project and the quality of the final result.

Rubric Criterion Level Quality	Rubric Criterion Level Score	Rubric Criterion Level Description
Proficient	3 points	The student's project has a hypothesis, a procedure, collected data, and analyzed results. The project is thorough and the findings are in agreement with the data collected. There are minor inaccuracies that do not affect the quality of the project.
Adequate	2 points	The student's project may have a hypothesis, a procedure, collected data, and analyzed results. The project is not as thorough as it could be; there are a few overlooked areas. The project has a few inaccuracies that affect the quality of the project.
Limited	1 point	The student's project may have a hypothesis, a procedure, collected data, and analyzed results. The project has several inaccuracies that affect the quality of the project.

Figure 1 | Example project rubric with CEDS elements

Figure 37. Holistic Rubric

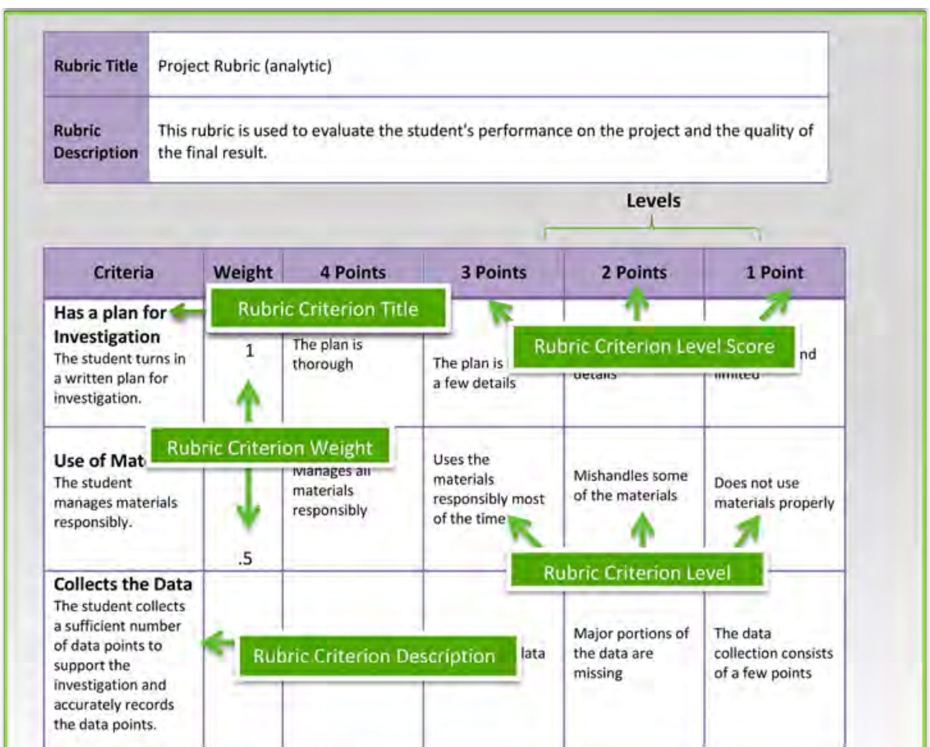


Figure 2 | Example project rubric with CEDS elements

Figure 38. Analytic Rubric

Learning Experience Record

Experience data is the data captured while students engage in learning experiences and online activities and is collected in the Learning Experience Record, integration point 16. When students engage in online learning experiences, every action that the student takes can become valuable data for use by teachers and the system to inform learning. It is impossible for a teacher to observe every learning experience for every student, but the experience data captured during hours of online learning experiences can give teachers at-a-glance indicators that may be used to optimize learning.

For example, a student may spend an hour online working through a set of math problems—getting some problems wrong on the first attempt, sometimes asking for a hint and sometimes branching off to a video to learn/relearn some part of the problem-solving process. The data from this hour-long experience can be summarized into an at-a-glance dashboard view with metrics like time between each attempt, which problems representing which skills were answered correctly, hint tally for each problem, etc. A teacher can make decisions to help the student in seconds by using data from an hour of "observation." The student can also get a birds-eye-view summary of the assessment-as-learning session and take ownership and self-direction.

These "clickstream" data are used to support student-centered learning as a source for predictive analytics, early warning systems and customized feedback to the learner. These experience data are also linked to achievement/competency data as detailed evidence of learning pathways and progress over time.

Assessing Soft Skills, Attitudes and Habits of Learning

Soft skills and other success factors, such as the learner's sense of ownership for learning, can be measured and become valuable inputs for the SCL IS. Some indicators, such as changes in attitudes about subject matter over time and the student's fixed or growth mindset, may be determined through surveys and other assessment instruments. Some indicators can be derived by analysis of patterns in experience data. Often these skills and success factors are being built into taxonomies in the Reference Framework so they can be linked to activities, resources and assessments.

Integrated Content, Activities, and Feedback Functions: Dashboards and Reports Functions

The results of assessments need to be reported back to the student through Dashboards and Reporting Functions, integration point 14, and accessed through the Online Learning Environment, integration point 15. The personalized workspace provides content within which the learner advances through competency-based pathways. From the learner's point of view, all of the online feedback and guidance directing this progression is "in" the workspace, but in reality, there may be separate systems supplying the learning maps, alerts, recommendations, social and collaborative learning as well as feedback to scaffold the transition between discrete learning experiences.

The PLP in the Dashboard/Reports includes the right amount of information to provide structure so the learner doesn't get lost, while supporting more than one path to a learning objective. System developers are experimenting to find the right balance between giving the learner the big-picture view and shielding the learner from complexity.

Evidence of Learning Functions

Evidence of Learning supports the tracking of achievement milestones reached by the student with links to the evidence and artifacts of that learning.

Achievement Tracking Component

Achievement Tracking data is based on evidence from the observations and measurements functions. Achievement Tracking also supports pulling in verifiable electronic records of a person's achievements or qualifications from organizations outside of the school setting in order to get a complete picture of learner competencies. The Achievement Tracking Component uses Assessment Results, Learning Experience Record Data and other Learner Specific Model data, integration points 17 and 18 in Figure 39.

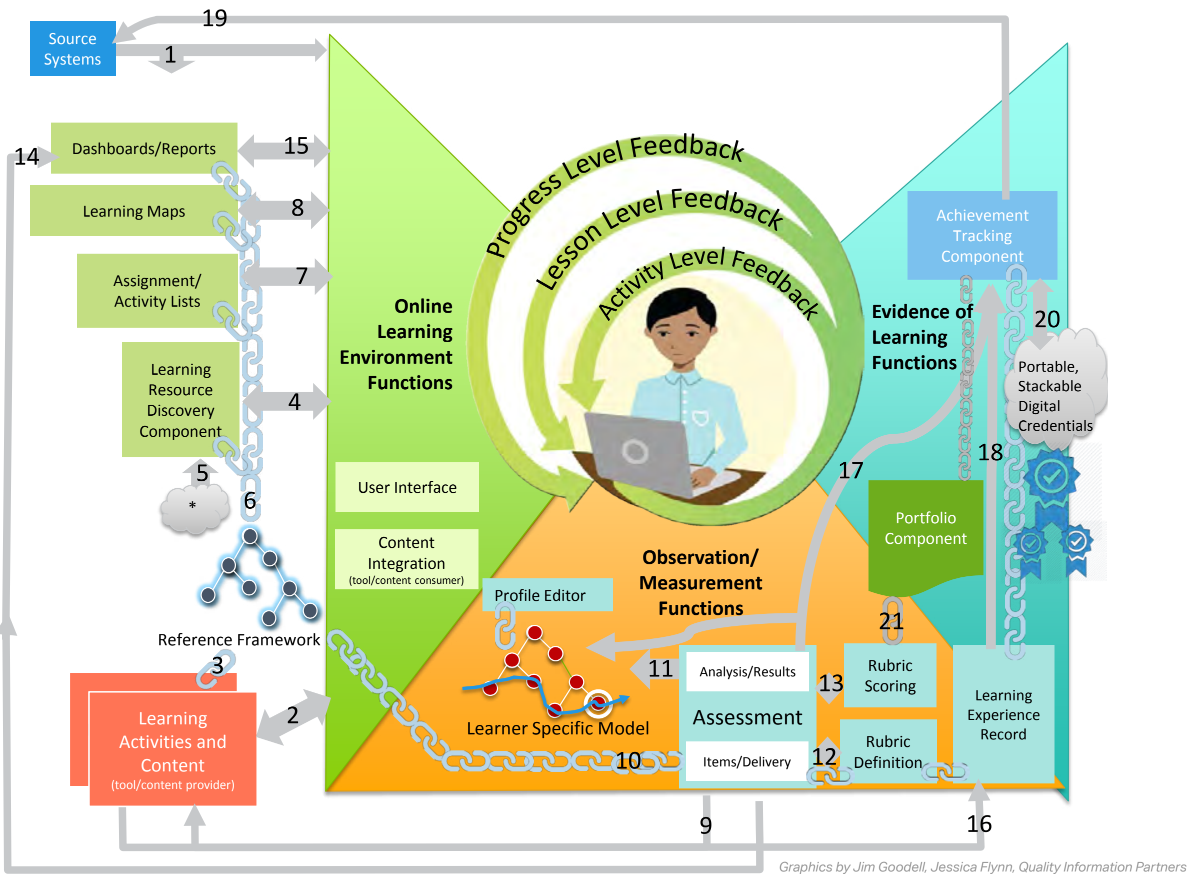


Figure 39. Evidence of Learning Functions

Artifacts of Learning (and Rubric Subsystems)

Artifacts of learning are digital representations of work products or digital proxies of tangible work products that give evidence to what a student has learned—for example, a written report, video or presentation. The SCL IS must include components for capturing artifacts of learning, evaluation of artifacts and linking artifacts to competency definitions.

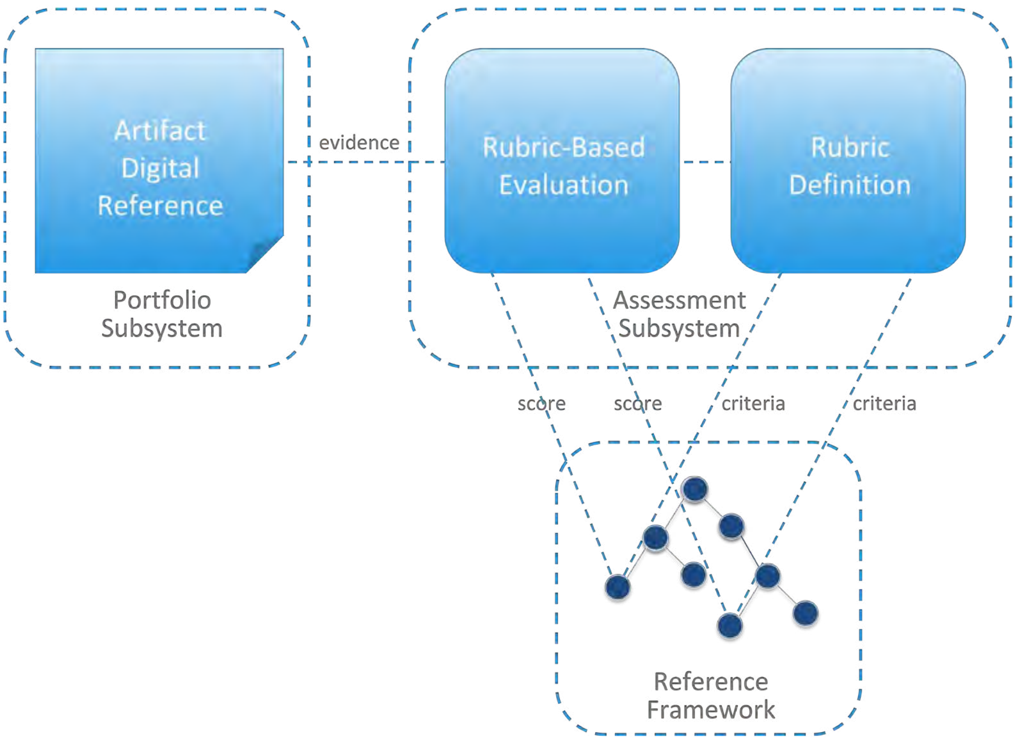


Figure 40. Linkage of Portfolio to Assessment to Reference Framework

Portfolio Component

The Portfolio Component provides the means to these store these artifacts of learning and links the evaluation of those artifacts to a rubric score, integration point 21 in Figure 39. For example, project-based learning work products may result in a video, photographs, report or presentation that may be captured digitally. The portfolio subsystem may be able to store the complete set of digital files for a work product or include references to work products stored elsewhere (such as a YouTube video). The record links the artifact to the learner and may include other metadata such as when and in what context (e.g., from an assignment) it was produced. An assessment of the work, such as a rubric-based evaluation and/or student reflection, will reference the record in the portfolio system along with the results according to competency-based evaluation criteria.

Students can demonstrate learning through presentation, which pulls from artifacts collection and additional student-developed material specific to the presentation; rubric can be associated with presentation, and both the student and teacher can score the rubric with the student being able to view both teacher and student scores. The

Achievement Tracking Component can include data from the rubrics and link to the actual portfolio artifacts as evidence of achievements, integration point 17.

Evaluation of Artifacts of Learning

Assessments of performance tasks that take place offline should be captured online. For example, a mobile app could be used by a teacher for real-time evaluation of a learner's performance on a task. An artifact such as a written report may be assessed using a rubric, which defines the rules for evaluating learning for one of more learning objectives. Components of the SCL IS include subsystems to define the rubric and to use the rubric as part of an evaluation. The results from evaluating with a rubric become data in the assessment results component of the SCL IS.

It is important that data captured to evaluate offline activities include more than just summative scores of the activity. For example, a teacher assessing a student's oral reading fluency may mark up a passage and use an instrument such as the DIBELS® Oral Reading Fluency to calculate a fluency score (word count per minute). Recording the fluency score online is helpful, but it may leave out important formative data, such as the mark-up indicating whether or not the student recognized an error based on context and self-corrected. When a rubric is used, the data should include the detailed assessment for each criterion, not just the overall score.

Artifacts of learning are only meaningful in the SCL IS when they are linked to the reference framework and a system of measurement, i.e., we need to know specifically what the artifact shows about student learning, what reference framework learning objectives are addressed and how we can measure learning for those learning objectives.

The evaluation of the artifact may be used in multiple ways:

- » To identify gaps (looking for specific weaknesses, inform feedback)
- » To recognize progress (recognize when certain thresholds have been met) for a specific competency
- » To recognize competency completion (as part of multiple measures)

Portable Stackable Digital Credentials

"Stackable" achievements/credentials refer to the ability to combine smaller achievements into larger achievements, for example—the set of learning objectives required to complete a unit, unit achievements adding up to course completion and multiple courses combining into a certificate or diploma. Achievement Tracking needs a way to pull in verifiable electronic records of a person's achievements or qualifications from other sources in order to get a complete picture of learner competencies. A transcript with letter or number grades from another school system is not good enough for student-centered learning. The data from Portable Stackable Digital Credentials is linked to the Achievement Tracking Component, integration point 20.

Learning maps may be combined with micro-credentials (digital badges) that recognize stackable achievements. The Open Badges initiative defines standards for embedding credential information into an image in a way that is interoperable across systems.

Social and Collaborative Learning Functions

The Social and Collaborative Learning Function enables and supports social and collaborative learning (learning from and working with others) and synchronous and asynchronous communication including tools like discussion boards, chats, webinars, email, Twitter and Facebook like tools that enable students to interact with each other, teachers and others involved in the student's education. It may also include project-based learning tools that allow students to work collaboratively and to manage project work. Online collaboration and communication tools also provide the means for educators and peers to give feedback to the learner and to fill gaps in understanding. This communication can be used with online or offline learning activities, during or after the activity.

The Social and Collaborative Learning Functions are accessed through the Online Learning Environment, integration point 22, using standards such as LTI™. Other standards support the exchange of data between such systems, such as Simple Mail Transfer Protocol (SMTP) for sending email.

> ***"The current LMS is often designed on the transmission model of education—a mechanism to transmit syllabi, content, and assessments. This process is important for the management of the course, but equal time must be given to collaboration, a true learning dimension."***
>
> *(The Next Generation Digital Learning Environment: A Report on Research, EDUCAUSE Learning Initiative, April 2015)*

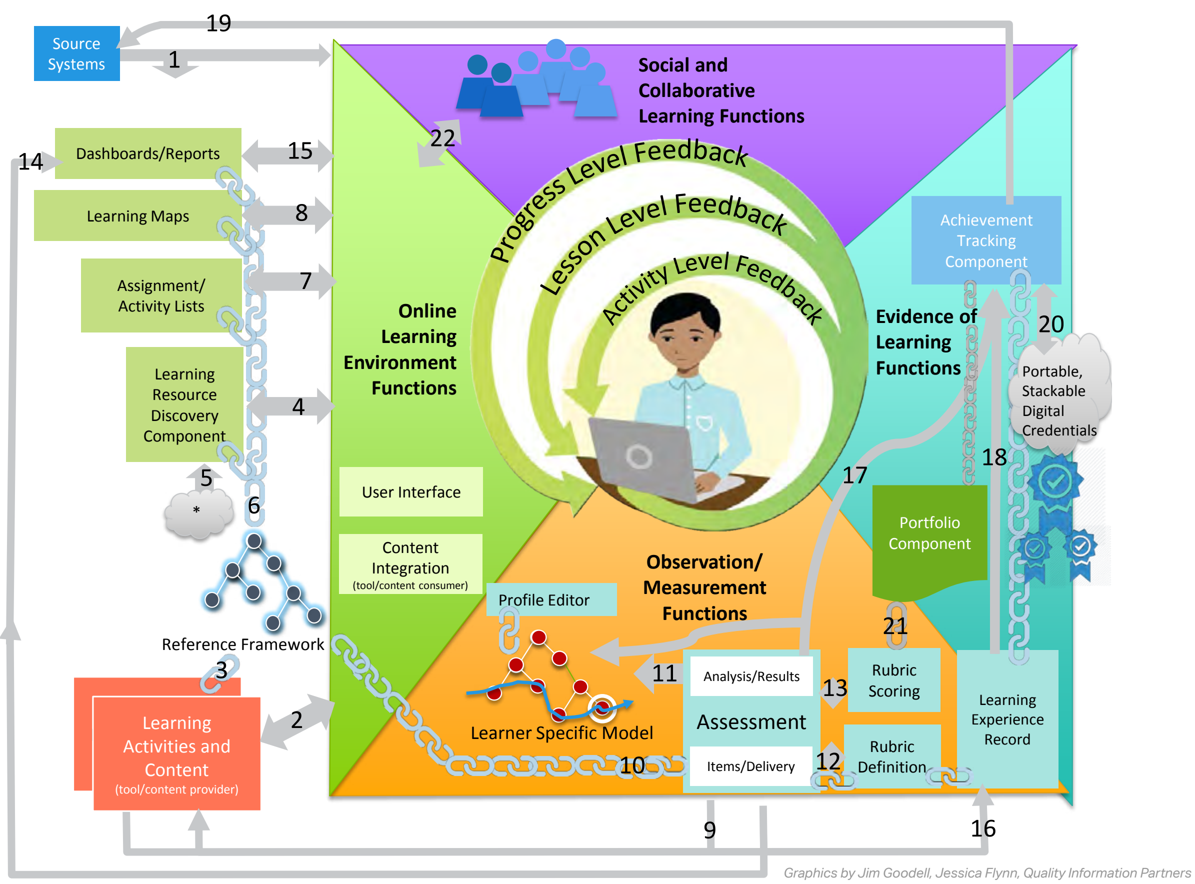


Figure 41. Social and Collaborative Learning Functions

Additional Integrated Content, Activities, and Feedback Functions

Recommendation/Analytic Engine Components

Recommendation/Analytic Engine Components (and other kinds of automation logic) are components that use business rules and technology like inference engines. Technologies, such as analytics engines and inference engines, work within and with other components such as Learner Specific Model and Achievement Tracking data to give feedback to the learner in various ways, such as dashboards, reports, alerts and real-time feedback presented within learning activities, integration points 23, 24, and 25. It pulls data from the Reference Framework, integration point 26. It sends data to Learning Maps to inform recommended pathways (29), to Assignment Lists (30), and to the Learning Resource Discovery component as cues for filtering based on learner needs and assertions about the quality of learning resources based on actual use (31).

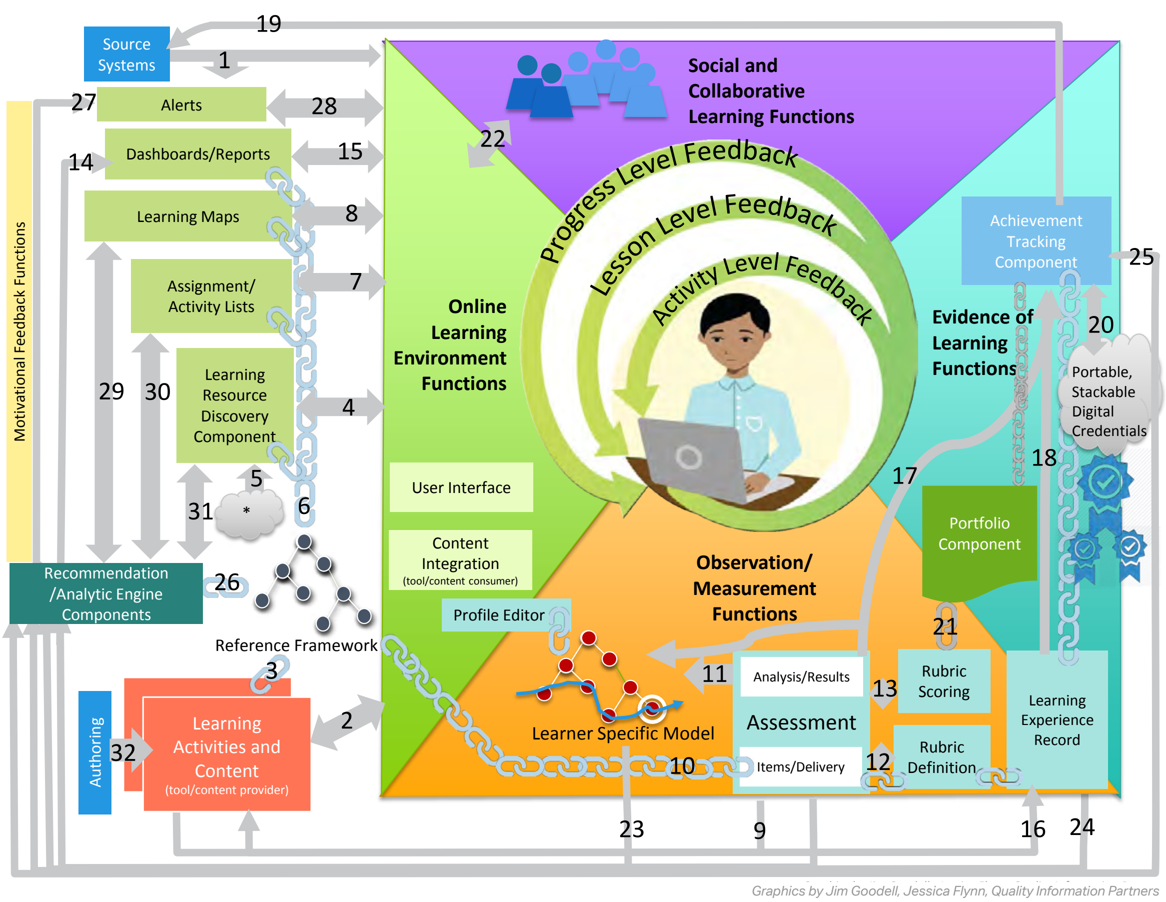


Figure 42. Recommendation/Analytic Engine Components

Alerts

Alerts are used to send email and text messages to users regarding performance, due dates, new information. The Recommendation/Analytic Engine Components and separate Student Motivation feedback systems may send data to trigger Alerts, integration point 28.

Motivational Feedback Functions

The personalized workspace is also a portal to the display of motivational feedback. The 2012 paper "Data Backpacks: Portable Records & Learner Profiles" suggested extending the student profile to include a "motivational profile that predicts persistence and performance."[17] Such a profile may include measures of "non-cognitive skills" and habits of practice that generally lead to successful learning.

Student motivation can include things like badges and awards, but the best systems of motivation will be personalized along with learning. Different things motivate each learner. The kind of motivational mechanics that are built into other kinds of online platforms, such as social media platforms and online games, can be applied to learning experiences. Motivation is multi-faceted. Different people respond to different motivators, thus building motivational mechanics into online interactions can be a challenge.

Yu-kai Chou's "Octalysis" defines eight categories of motivational mechanics (also called "game mechanics"):

» Meaning
» Accomplishment
» Empowerment
» Ownership
» Social Influence
» Scarcity
» Unpredictability
» Avoidance

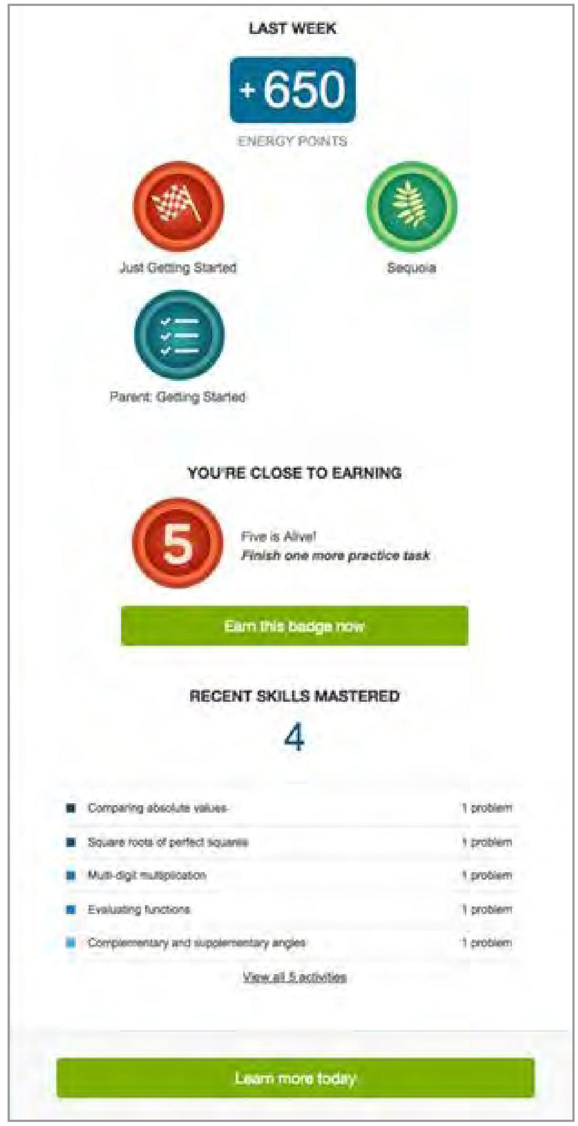


Figure 43. Motivational Feedback from Khan Academy

Each category has a number of techniques that serve as motivational catalysts. These techniques may be built into the specific learning activities or into the sequence of activities offered to the learner. For example, making certain kinds of activities or system functions available only for certain/random time periods may tap into the Scarcity and Unpredictability motivators, making the learner want to do those things more than if they were always available. Some game mechanics may be built into learning experience delivery.

The use of game mechanics in education is still relatively undeveloped compared to its application in other domains such as social media, online gaming, marketing and corporate training. This presents an area of opportunity for the SCL IS developers.

17. Bailey, John, Carter, Samuel Casey, Schneider, Carri and Vander Ark, Tom. "DLN Smart Series—Data Backpacks: Portable Records & Learner Profiles." October 2012. http://digitallearningnow.com/site/uploads/2012/10/DLN-Smart-Series-Databack-Final1.pdf

Authoring Functions

The SCL IS will not work without components such as Authoring tools. Any role given permission within the system can author content, including students. This is integration point 32 . Whether these content objects are made available to others within the system should be a policy issue rather than a technical one.

Teacher Interaction

The views presented previously have been from a student-centric view of the functions. In the following graphic, the blue arrows show how educators might interact with some of the same components that are shown for the student.

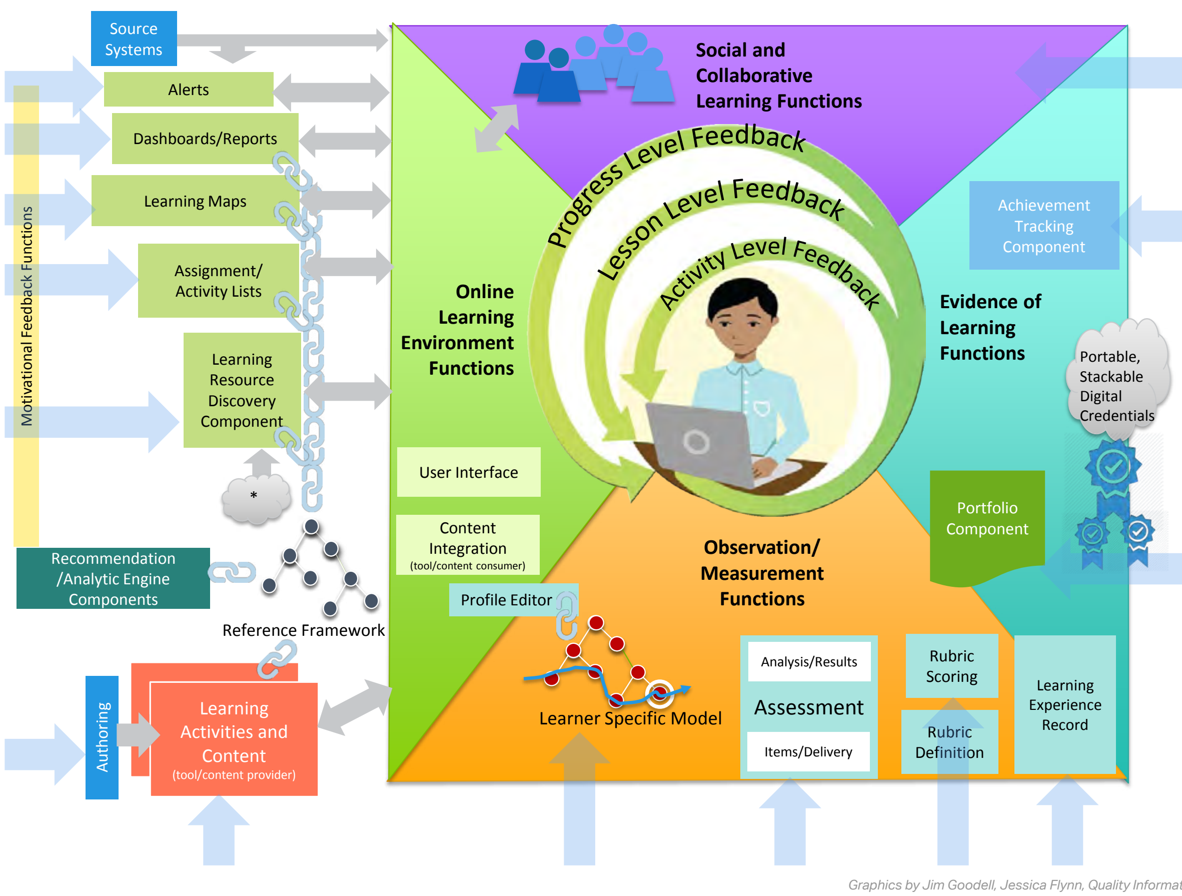


Figure 44. Teacher Interaction Points with the System

Different systems may bundle functional components differently, but this model shows the key parts and how they need to integrate. The design depends on the use of data and technical standards to support integrations.

Points of Integration

This design shows the core system functionalities provided by enabling technologies and the points at which the subsystems must integrate.[18] The integration points, shown as arrows or chains on the diagram, are numbered (in no particular order) for more information about the kind of integration needed. Note: Additional components addressing the roles of teachers, parents and school administration in supporting student-centered learning are not shown, but also require integration with these components.

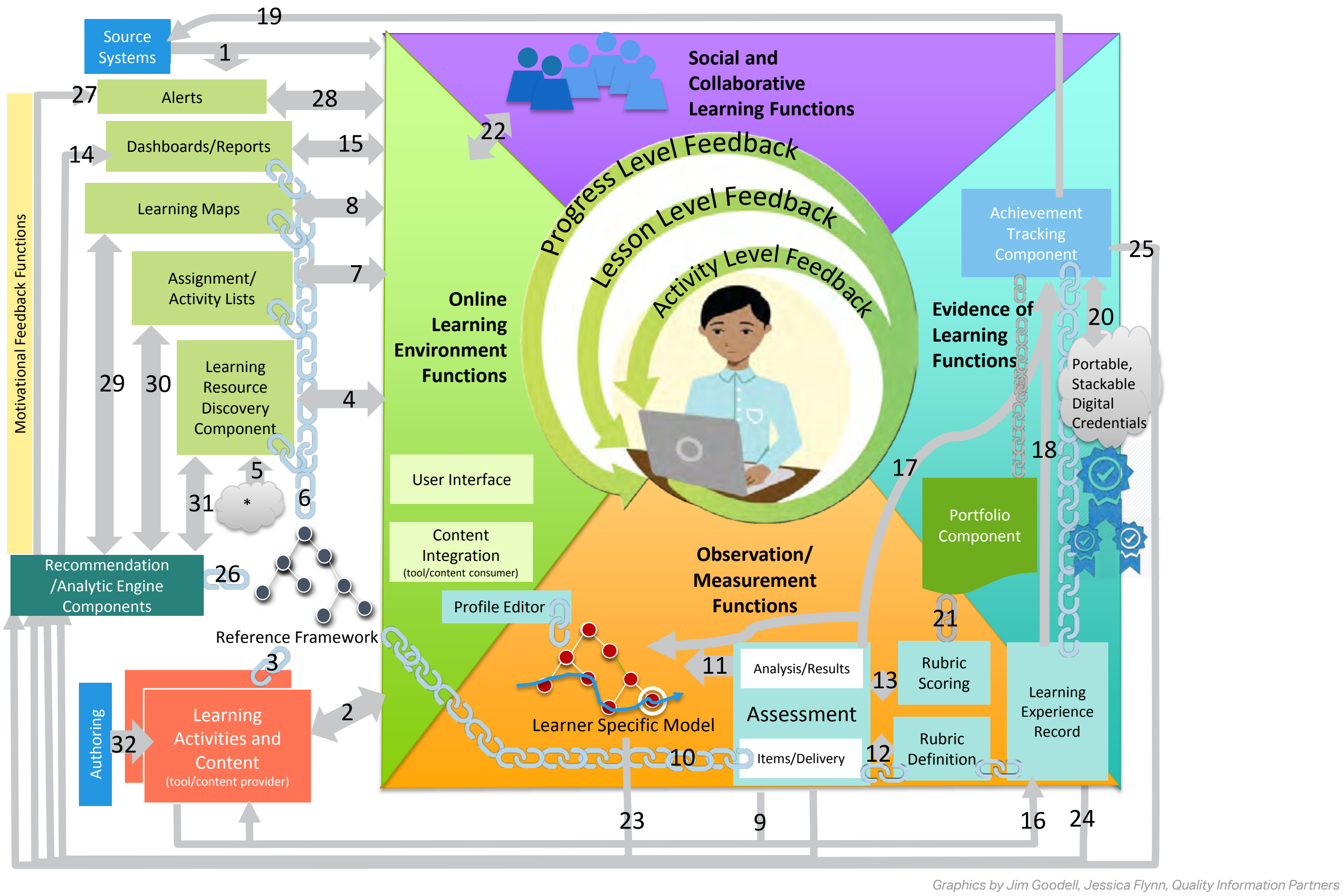


Figure 45. Points of Integration

The following list defines the kind of integration that takes place for each of the numbered integration points. In the next section, the data and technical standards that support each kind of integration will be described.

1. Class roster and student data is provided from the source systems (student information system or alternative system of record for rosters) to the student workspace, online learning software, collaboration software, dashboards, portfolio systems and reporting software. The roster information is used to inform authorization rules. Other student information, such as disabilities information may be used to personalize the learning experience. Many institutions use SIF to support rostering.

18. It is beyond the scope of this paper to get into the nuances of data governance for the SCL IS; however, the quality of the data depends on business rules and implementation of human and automated processes. This is especially important when multiple software applications collect/store/report the same data (e.g., student name) in different places and for different purposes.

2. Learning activities are presented within the content of the personal workspace. The integration may use content packaging standards such as SCORM and Common Cartridge or standards to display an external Web application within a web page such as LTI™.
3. Learning activities and content link to relevant nodes in a Reference Framework using a URL as a globally unique identifier. The URL may also be a reference to a hosted representation of the framework node, such as with an ASN service.
4. Learning Resource Discovery Tools are made available within the personal workspace using application integration technologies such as defined in the LTI™ standard.
5. Learning Resource Discovery Tools may use a catalog that is fed learning resource metadata from sources such as the Learning Registry or other learning object catalogs with standards based (LRMI/CEDS) metadata.
6. Content referenced within Learning Resource Discovery Tools, Assignments/Activities Lists, Learning Maps and Dashboard/Reports all may link to relevant nodes within a Reference Framework.
7. Assignments/Activities Lists are made available within the personal workspace using application integration technologies such as defined in the LTI™ standard and behind-the-scenes data integration standards such as the Schools Interoperability Framework (SIF).
8. Learning Maps are made available within the personal workspace using application integration technologies such as defined in the LTI™ standard.
9. Assessment items are a kind of content that must be packaged for movement to the delivery system. (LTI™, Common Cartridge™, SIF)
10. Assessment Items and Tests link to relevant nodes within a Reference Framework. (e.g., ASN)
11. Assessment Result data must feed into the Learner Model. (e.g., SIF, IMS Caliper Analytics™)
12. Rubric Definition data is defined within an application and linked to Assessment Items for scoring. (CEDS, QTI™, SIF)
13. Assessment Result data is linked to criterion levels in a Rubric or performance levels defined as part of the test form. (CEDS, QTI™, SIF)
14. Assessment Result data is moved to a dashboard or reporting component. (e.g., Ed-Fi, SIF, IMS Caliper Analytics™)
15. Dashboard/Reports are made available within the personal workspace using application integration technologies such as defined in the LTI™ standard.
16. Learner interactions with Learning Activities and Content are captured by the delivery application and that experience data is sent (using xAPI or Sensor API) to the Learning Record Component.
17. Achievement Tracking Component uses Assessment Results and other Learner Specific Model data. (e.g., Ed-Fi, SIF, QTI-results)
18. The Achievement Tracking Component may query the Learning Record Component for outcome data. (using xAPI or Sensor API)
19. The Achievement Tracking Component may inform a gradebook, either as part of the Student Information System or as a Separate Application.
20. Metadata from Portable Stackable Digital Credentials (e.g., Extended Transcript, OpenBadges) may be harvested to inform the Achievement Tracking Component.
21. Artifacts contained within the Portfolio Component are linked to the Rubric Scoring and Assessment Results

components.

22. Social and Collaborative Learning and Collaboration components are made available within the personal workspace using application integration technologies such as defined in the LTI™ standard.
23. Recommendation/Analytic Engine Components Engines use data from the Learner Model, including assessment results.
24. Recommendation/Analytic Engine Components Engines query the Learning Experience Record Component for data.
25. Recommendation/Analytic Engine Components Engines may use data from the Achievement Tracking Component, including metadata from Portable Stackable Digital Credentials, for more informed recommendations.
26. Recommendation/Analytic Engine Components Engines use the Reference Framework, including competency definitions and competency pathway options.
27. Recommendation/Analytic Engine Components Engines or separate motivational feedback systems may send data to trigger Alerts.
28. The Alert Component uses standards such as SMTP, SMS to send email and text messages.
29. Recommendation/Analytic Engine Components Engines send data to Learning Maps to inform recommended pathways.
30. Recommendation/Analytic Engine Components Engines send data to Assignment Lists.
31. Recommendation/Analytic Engine Components Engines send data to the Learning Resource Discovery component as cues for filtering based on learner needs and assertions about the quality of learning resources based on actual use. (Assertions may also be sent to the Learning Registry and external metadata repositories with standard metadata formats and vocabulary defined within LRMI, CEDS and SIF.)

DATA STANDARDS AND INTEROPERABILITY

Standards for Integrating Content and Remote Applications

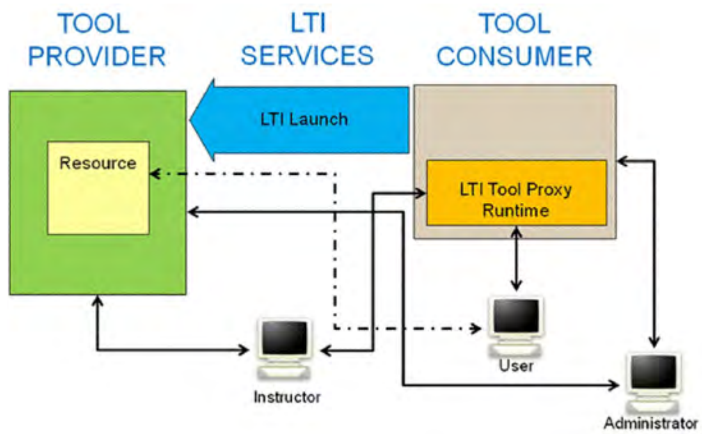
Integrated learning systems use standards to integrate content either by importing that content or launching a remote application that provides the learning experience.

IMS Global has several standards used for embedding content or tools into an existing application, such as a LMS:

- Common Cartridge™ – A standard for packaging learning content for discovery and delivery within a learning management system. It includes a standard for the metadata describing the content in the cartridge.
- "Thin Common Cartridge" – Based on Common Cartridge, but instead of packaging the content for transport "thin common cartridge," only includes metadata and a link to the content. The content may be a Learning Tools Interoperability® (LTI®) enabled link or Web link only.
- Question and Test InteroperabilityTM (QTITM) – A standard for packaging and delivering assessments and assessment items.
- Learning Tools InteroperabilityTM (LTITM) – A standard for application interoperability between learning tools, i.e., software applications working together.

Single Sign on

IMS Global's LTI specifications allow remote applications and content to be integrated into a user's interaction within a LMS. The specification allows an LMS to launch an external Web application in a new browser window and to send that application the information needed to personalize the experience. The spec handles single sign-on so it looks to the user that it is all the same system. The remote application can also send information back to the host LMS as part of an LTI session. The single sign-on part of LTI makes use of technology standards that are not specific to education such as the OAuth authentication protocol.



Source: https://www.imsglobal.org/specs/ltiv2p0/

Figure 46. LTI® Overview

There are other standard protocols for handling single sign-on and launching an external Web resource or application. One such protocol is the Security Assertion Markup Language (SAML) that handles Web browser single sign-on. The user experience is the same as with LTI; it launches the external Web application in a new browser window and sends the application identity information needed to personalize the experience. For example, teachers across the state of Georgia can access a state-provided data dashboard from their local Student Information Systems because the systems have been integrated using the SAML protocol.

Content and Assessment Integration

Common Cartridge is an IMS Global specification for packaging digital content so that it may be moved from an authoring system into an LMS. The standard supports various types of content, such as files that are widely supported for delivery over the Web (HTML files, images, audio, video, MS Office, PDF, Flash, etc.), discussion topics, assessments, interactive whiteboard files, electronic books and links to Web resources.

Sharable Content Object Reference Model (SCORM) is another well-established standard for learning content shared across systems. SCORM, and its successor Experience API (xAPI), are products of the Advanced Distributed Learning Initiative, established in 1997 as a public-private partnership to standardize and modernize training and education management and delivery within U.S. government agencies, including the military. The SCORM standard is the required or preferred approach for training developed by and for key U.S. government agencies, but it also has been voluntarily adopted by corporate training and higher education entities around the world. (https://www.adlnet.gov/scorm/, http://scorm.com/scorm-solved/scorm-engine/scorm-engine-more/scorm-engine-clients/)

Many content-authoring tools support both Common Cartridge and SCORM packaging. The tools will typically provide forms to collect the required metadata and tools to package the files into a zip file for import into the LMS or content repository.

QTI

"IMS Question & Test Interoperability (QTI®) specification enables the exchange of item, test and results data between authoring tools, item banks, test construction tools, learning systems and assessment delivery systems." (https://www.imsglobal.org/question/index.html)

QTI works with IMS's Common Cartridge specification. One kind of cartridge is used to package the information needed to launch an LTI session for delivering an online assessment to a student.

Reference Framework Data Standards

Reference frameworks are typically defined as a hierarchy of statements with the subject matter context at the top (e.g., Mathematics), one or more levels of classifying statements (e.g., Number and Operations), and one or more levels of competency definitions. Data standards exist for encoding and storing reference competency frameworks in machine-readable form and for using these standards framework in models for competency-based pathways. The data standards provide a flexible structure that supports any number of levels of granularity.

The standards also support adding levels to support specific purposes, for example adding "indicator" nodes under a competency node that describe ways of measuring that a learner has achieved a competency. This is important because many publicly published learning standards frameworks typically don't include levels of granularity or rules for measurement needed to fully support the system of learning. The flexibility offered by the standards allows for defining a set of micro-competencies that make up the parent competency in the hierarchy.

There are some general purpose standards such as the Simple Knowledge Organization Systems (SKOS) that can be used to specify reference frameworks and some education-specific standards. Three commonly used sets of data standards that support reference frameworks for student-centered learning are the Achievement Standards Network Protocol, SIF and Common Education Data Standards.

Achievement Standards Network Protocol

The Achievement Standards Network (ASN) Protocol is a standard for encoding and publishing competency framework data in machine-readable form. Educational frameworks must be available as machine-readable data, rather than prose documents, to support alignment between resources and learning standards. ASN provides a lightweight and flexible structure as statements that are individually identified, described and related using constructs understandable by computers. The ASN Protocol uses an entity-relationship model with two entities: *Standard Document* and *Statement*. These entities are each assigned an inherently, globally-unique *Uniform Resource Identifier (URI)*. (http://asn.desire2learn.com/content/how-asn-works, http://asn.desire2learn.com/content/asn-resolution-service-overview)

The ASN Application Profile is flexible enough to deal with a variety of educational frameworks, and it has been brought into alignment with other standards referencing learning standards, including Common Education Data Standards (CEDS), Schools Interoperability Framework (SIF) and IMS Content Packaging. (http://www.australiancurriculum.edu.au/technical)

ASN is also an open-access service for competency framework data. It was originally developed by Professor Stuart Sutton, PhD, JD, LLM, at the Information School, University of Washington, in collaboration with JES & Co. through National Science Foundation awards, with subsequent support from the Bill & Melinda Gates Foundation and licensed to JES & Co. under agreement with the University of Washington. As of February 2014, the ASN was owned operated by D2L (http://www.d2l.com/). ASN data, hosted at http://asn.desire2learn.com/, is free to use in any manner under a Creative Commons Attribution license.

Common Education Data Standards (CEDS) and SIF 3x data model

CEDS and the SIF 3x data model align with the ASN Protocol and include reference models showing competency data as it may exist in a relational database, including relationships to learning resources, assessment and student achievements. The SIF 3x data model incorporates CEDS for data transport between systems.

CEDS defines a set of properties for the framework as a whole and each node in a framework. These properties include those used to support competency frameworks used in different contexts: as information made publicly available on the Web, with each node in the framework available as a separate URL (such as ASN); those used for transporting framework data between systems (e.g., the SIF 3x data model); and references to competency information within packages of content (IMS). CEDS also has standard elements that reflect properties to support "dynamic learning maps," i.e., maps that define alternate pathways based on learner needs such as an alternative wording/meaning of a reading competency for a learner that is visually impaired.

At a conceptual level, the various technical standards all model competency information as:

- information about the overall framework;
- information about each node in the framework; and
- information about the relationship between nodes.

CEDS also includes data elements for:

- Achievement Criteria: The criteria for competency-based completion of the achievement/award.
- Competency Set Completion Criteria: The criteria for the set of competencies that represent completion or partial completion of a unit, course, program, degree, certification or other achievement/award. Specifies whether completion requires achievement of all items in the set or some number of items.
- Competency Set Completion Criteria Threshold: The minimum number of competencies in the set that must be achieved for completion or partial completion of a unit, course, program, degree, certification or other achievement/award.

Competencies and Dynamic Learning Maps

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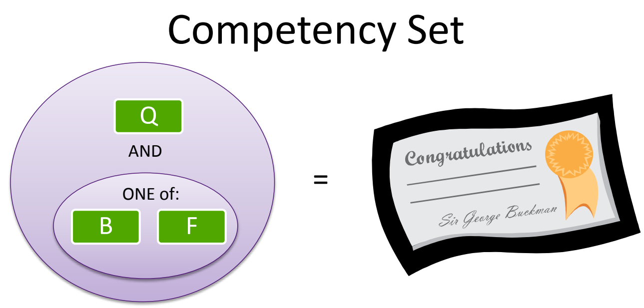

Figure 47. CEDS Defines a Standard for Competency-based Completion Criteria Data

CEDS defines a data standard for a set of rules to determine competency attainment using:

- Competency Set – a structure for grouping a set of competencies; and
- Completion Criteria – criteria for the set of competencies that represent completion or partial completion of a unit, course, program, degree, certification or other achievement/award.

CEDS also has standard elements that reflect properties to support "dynamic learning maps," i.e., maps that define alternate pathways based on learner needs such as an alternative wording/meaning of a reading competency for a learner that is visually impaired.

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- Competency Set Completion Criteria Threshold: The minimum number of competencies in the set that must be achieved for completion or partial completion of a unit, course, program, degree, certification or other achievement/award.

Data Standards for Assessment

CEDS includes data element definitions that cover all areas of assessment including design, delivery, registration, results and alignment to competencies. The CEDS elements were developed in cooperation with and informed by the work of other standards bodies such as IMS Global (QTI™, Accessible Portable Item Protocol) and SIF.

QTI™ is a standard for packaging question and test content for interoperability between systems.

The Accessible Portable Item Protocol (APIP) is a standard for packaging test items with the information needed to make them accessible for students with a variety of disabilities and special needs. (http://www.imsglobal.org/apip/)

SIF 3x includes the CEDS data elements and standards such as packaging and transport of data for registration and administration of assessments.

In 2012 IMS Global, SIFA (now A4L) and CEDS worked together on the **Assessment Interoperability Framework (AIF)**, a framework that defines the interoperability touch points across the educational technology standards to support the full assessment lifecycle. Even though AIF focused on summative assessments, many of the standards can also be applied to the formative assessment process used for student-centered learning.

Experience Data Standards

Experience API

Experience API (xAPI) is a specification defining standards for storing and providing access to information about learning experiences. The xAPI enables the tracking of learning experiences, including traditional records, such as scores or completion. It also stores records of learners' actions, like reading an article or watching a training video. The xAPI was developed by the Advanced Distributed Learning Initiative (ADL) as a successor to ADL's previous SCORM® standard. The xAPI is designed to support existing SCORM use cases as well as enable the use cases that were difficult to meet with SCORM, such as mobile training and content that is accessed outside of a Web browser. xAPI is an established standard with initial implementations in professional and military training and is gaining interest in academia.

The xAPI statement has three core parts:

1. an actor (e.g., the learner)
2. a verb (e.g., "answered")
3. an object (e.g., a specific assessment question).

Each statement also has a timestamp, and may have a result value, context information and attachments. Version 1.02 of xAPI specifies the following properties:

PROPERTY	TYPE	DESCRIPTION	REQUIRED
Id	UUID	UUID assigned by LRS if not set by the Activity Provider.	Recommended
actor	Object	Who the Statement is about, as an Agent or Group Object. Represents the "I" in "I Did This"	Required
verb	Object	Action of the Learner or Team Object. Represents the "Did" in "I Did This"	Required
object	Object	Activity, Agent or another Statement that is the Object of the Statement. Represents the "This" in "I Did This". Note that Objects which are provided as a value for this field should include an "object Type" field. If not specified, the Object is assumed to be an Activity.	Required
result	Object	Result Object, further details representing a measured outcome relevant to the specified Verb.	Optional
context	Object	Context that gives the Statement more meaning. Examples: a team the Actor is working with, altitude at which a scenario was attempted in a flight simulator.	Optional
timestamp	Date/Time	Timestamp (Formatted according to ISO 8601) of when the events described within this Statement occurred. If not provided, LRS should set this to the value of "stored" time.	Optional
stored	Date/Time	Timestamp (Formatted according to ISO 8601) of when this Statement was recorded. Set by LRS.	Set by LRS
authority	Object	Agent who is asserting this Statement is true. Verified by the LRS based on authentication and set by LRS if left blank.	Optional
version	Version	The Statement's associated xAPI version, formatted according to Semantic Versioning 1.0.0.	Not Recommended
attachments	Array of attachment Objects	Headers for attachments to the Statement	Optional

IMS Caliper Analytics™

IMS Global Learning Consortium's analytics standard Caliper Analytics™ includes the Sensor API for collecting learning experiences. The IMS standard is also designed to support actor-verb-object statements (and is being designed to consume xAPI statements). Caliper, however, is tightly integrated with other IMS standards, such as LTI, LIS and QTI. For example, the standard payload for a Sensor experience record may include the identifier from an LTI session (federatedSessionId), and the Sensor actions collected during assessment delivered using the QTI standard will align with that standard.

IMS is also developing "metric profiles," sets of common labels for learning activity data to be encoded with Sensor and interpreted by systems using Caliper Analytics.

The recently released IMS standard more formally packages the learner action with information about the context (course section) and activity (a quiz). xAPI statements can also reference this kind of context information, however, for systems designed to use the other IMS standards (LTI, LIS, QTI). Caliper Sensor promises to offer a coherent approach to application integration, information services and assessment-related event data.

The Caliper Analytics™ specification includes "Metric Profiles" that define controlled vocabulary for events and entities. The Metric Profiles are organized by Learning Activity type such as "Reading", "Assessment" and "Outcome".

Common Education Data Standards

The Common Education Data Standards define "Learner Action" using these data elements:

- **Actor**: Learner Action Actor Identifier
- **Verb**: Learner Action Type
- **Object**: Learner Action Object Description, Learner Action Object Identifier, Learner Action Object Type
- **Result**: Learner Action Value
- **Timestamp**: Learner Action Date Time

For example, (a student) (attempted) (an assessment problem) (value entered) at (date/time). This example might be followed by another statement with the outcome of the attempt, such as (a student) (passed/failed/scored) (an assessment problem) (score value) at (date/time).

The standards also provide logical models for contextual data to be linked to learner actions, e.g., the attempted assessment item is part of a quiz or follow-up to the student watching a video.

CEDS is a standard data vocabulary that serves to bridge various technical standards and researchers, policymakers and system implementers. To that end, CEDS includes a standard set of verbs and their definitions to use in experience data statements, based on xAPI verbs and other sources such as research-based intelligent tutoring systems:

answered	The person gave a correct answer or solution.
asked	The person inquired about something, or sought an answer to a question or problem.
attempted	The person made an effort or attempt.
attended	The person was present.
commented	The person made or wrote a comment.
completed	The person finished or ended the specified activity or object.
exited	The person moved out of or departed from interaction with the specified activity or object.
experienced	The person participated in or underwent.
failed	The person was unsuccessful with the specified activity or object.
imported	The person transferred the specified information object into a data store.
initialized	The person assigned an initial value to the specified activity or object.
interacted	The person acted with or towards the object of the statement.

launched	The person gave impetus to the object of the statement.
mastered	The person became completely proficient or skilled in a competency.
passed	The person achieved a successful result from an evaluation or a selection process.
preferred	The person selected the object as an alternative over another.
progressed	The person moved forward.
registered	The person enrolled in or was recorded as a candidate for.
responded	The person showed a response or a reaction to.
resumed	The person returned to a previous location or condition within an activity.
scored	The person recorded the result of assigned a grade or rank to an evaluation of the specified object or activity.
shared	The person made the specified object available for use by others.
suspended	The person made the specified object or activity come to an end or stop.
terminated	The person brought the object or activity to a final end.
voided	The person declared the object or activity invalid.

https://ceds.ed.gov/pdf/CEDS-Addresses-Learner-Experiences.pdf

Analytics Store vs. Learning Record Store
Learner experience data captured by a single learning experience or online application has limited value by itself. Standards like xAPI and Caliper are designed for analysis of data across learning experiences to optimize feedback and to in turn optimize student learning. Therefore, experience data from multiple systems needs to be brought together.

The xAPI specification defines a system for collecting experience data, independent of the learning management system. The "Learning Record Store" (LRS) is a system that stores xAPI statements communicated through xAPI (http://adlnet.gov/adl-lrs/). ADL has developed an open source proof of concept LRS and examples (http://adlnet.gov/adl-research/performance-tracking-analysis/experience-api/xapi-adopters/).

IMS Caliper calls for an "Analytics Store" to keep the learning experience records, leaving it to vendors to develop the technology for storing the records. According to an IMS whitepaper, "the Analytics Service and any associated services such as the access and store interfaces and stack, are outside the scope of the IMS Caliper framework from a standards based framework perspective." (http://www.imsglobal.org/IMSLearningAnalyticsWP.pdf)

Standards for Rubrics

CEDS and the SIF 3x define data elements for defining and using a rubric.

Common Elements:

ELEMENT NAME	DEFINITION
Rubric Title	The title of the rubric.
Rubric Description	Text describing the intended use of the rubric.
Rubric Identifier	An identifier assigned to a rubric.
Rubric URL Reference	The URL location where the rubric may be found.

Additional elements for a Holistic Rubric:

ELEMENT NAME	DEFINITION
Rubric Criterion Level Quality Label	Text describing a criterion that must be met to demonstrate quality for a product, process, or performance task.
Rubric Criterion Level Score	The points awarded for achieving this level.
Rubric Criterion Level Description	Text describing one or more benchmarks that must be met to achieve a degree of achievement on a product, process, or performance task.
Rubric Criterion Category	A textual label for category by which Rubric Criterion may be grouped.

Rubric Title	Project Rubric (holistic)
Rubric Description	This rubric is used to evaluate the student's performance on the project and the quality of the final result.

Rubric Criterion Level Quality	Rubric Criterion Level Score	Rubric Criterion Level Description
Proficient	3 points	The student's project has a hypothesis, a procedure, collected data, and analyzed results. The project is thorough and the findings are in agreement with the data collected. There are minor inaccuracies that do not affect the quality of the project.
Adequate	2 points	The student's project may have a hypothesis, a procedure, collected data, and analyzed results. The project is not as thorough as it could be; there are a few overlooked areas. The project has a few inaccuracies that affect the quality of the project.
Limited	1 point	The student's project may have a hypothesis, a procedure, collected data, and analyzed results. The project has several inaccuracies that affect the quality of the project.

Figure 1 | Example project rubric with CEDS elements

Additional elements for an Analytic Rubric:

ELEMENT NAME	DEFINITION
Rubric Criterion Title	The title of the rubric.
Rubric Criterion Weight	A numeric weight assigned to this Rubric Criterion, used for scored rubrics.
Rubric Criterion Category	A textual label for category by which Rubric Criterion may be grouped.
Rubric Criterion Description	Text describing the intended use of the rubric.
Rubric Criterion Position	A numeric value representing this criterion's position in the criteria list for this rubric.
Rubric Criterion Level Description	Text describing one or more benchmarks that must be met to achieve a degree of achievement on a product, process, or performance task.
Rubric Criterion Level Feedback	Pre-defined feedback text to be relayed to the person or organization being evaluated. This may include guidance and suggestions for improvement or development.
Rubric Criterion Level Position	A numeric value representing the level's position in the list of levels defined for the Rubric Criterion.
Rubric Criterion Level Quality Label	A qualitative description of this degree of achievement used for column headers or row labels in tabular rubrics.
Rubric Criterion Level Score	The points awarded for achieving this level.

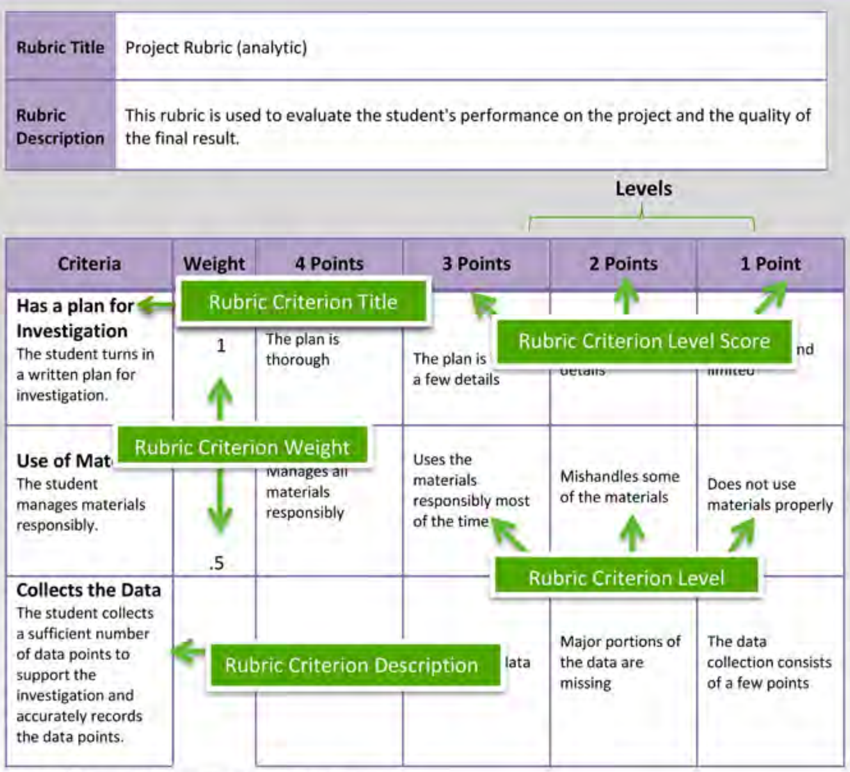


Figure 2 | Example project rubric with CEDS elements

Standards Supporting Learning Resource Discovery

Emerging standards are making it possible for education organizations to share catalogs of learning resources.

The Learning Resource Metadata Initiative (LRMI) began in 2011 shortly after the announcement of Schema.org, a search engine-backed standard for tagging content on the Web. The initiative defines "tags" that may be included in Web pages to make those pages discoverable online.

LRMI defines a lightweight set of metadata properties that describe the instructional intent of a Web page, resource or piece of content. The resulting LRMI specification version 1.1 was accepted as an official extension of Schema.org in April 2013. After adoption, the Dublin Core Metadata Initiative (http://dublincore.org) took over stewardship of LRMI. (See http://dublincore.org/dcx/lrmi-terms/1.1/).

Figure 48. The Learning Resource Metadata Initiative and the Dublin Core Metadata Initiative

CEDS Vocabulary for Metadata and Aligning Resources to Learning Objectives

The CEDS vocabulary for learning resources builds on the LRMI elements by defining a set of possible values for applicable elements.

For example, rather than leave "Learning Resource Type" open to interpretation, the CEDS vocabulary defines a limited number of options, such as:

» Learning Activity - Activities engaged in by the learner for the purpose of acquiring certain skills, concepts or knowledge, whether guided by an instructor or not. A Lesson may define one or more learning activities; and
» Assessment Item - A specific prompt that defines a question or protocol for a measurable activity that triggers a response from a person used to determine whether the person has mastered a learning objective.

Some of the option sets are based on other standards. For example, "Digital Media Type" values are based on the media types defined by the Internet Assigned Numbers Authority (IANA) at http://www.iana.org/assignments/media-types.

Thirteen state education agencies were involved in developing the option sets adopted by CEDS for elements such as "Learning Resource Type." CEDS also has elements that align with the Learning Registry approach to rating resources.

CEDS also includes standard data vocabulary and models for aligning resources to learning objectives.

For details on the CEDS vocabulary for learning resources, visit https://ceds.ed.gov/domainEntitySchema.aspx, and browse the "Learning Resources" and "Learning Standards" folders.

Open Archives Initiative for Metadata Harvesting (OAI-MPH) and SQI

Digital content is often stored in specific digital libraries, called Learning Object Repositories (LOR). These systems typically provide a Web interface to allow the searching of education resources through the metadata. One of the main characteristics of these LORs is their heterogeneity; therefore, the interoperability among LORs is limited. However, to deal with this issue, they typically have a layer (interface) to make external access possible through an external search agent and, hence, the interoperability. There are different standards or specifications that focus on this interoperability layer, mainly OAI-MPH (Open Archives Initiative for Metadata Harvesting) and SQI (Simple Query Interface).

BEYOND THE STUDENT-CENTERED LEARNING DELIVERY SYSTEMS

Beyond the systems that directly enable student-centered learning and teaching are the dependent functions such as curriculum management, student information, registration/enrollment, security, assessment results, administrative dashboards and analytics.

Identity Provider (Single Sign On)

As noted in earlier sections, there are multiple technology standards that support single sign-on. Education agencies must determine which system and authentication method will be the identify provider for the SCL IS, that is, which system users will use to sign in and to authenticate who they are. This might be a district-hosted authentication system, a cloud-based service (such as Google Apps for Education) or the personal workspace/ online portal provided by a learning management system.

Authentication standards such as OAuth, SAML and OpenID allow multiple applications to trust the authenticated identity. Other applications trust the authentication provider so users don't have to log into every application.

After a user has been authenticated by the identity provider, each application must manage authorization. Authorization is the process within each system that determines if a person has permission to view data or use a software feature. In education data system authorization, rules are often determined based on a person's role within an organization or related to a course section. The system of record for this kind of data is often the student information system.

Student Information Systems/Student Management Systems/Human Resources

The online environment needs some information from the district source systems (SIS, HR) for bringing students and staff into the system and associating them with the correct course or content stands.

The SIS/SMS supports the administrative functions of local education agencies and schools. These systems support registering, scheduling, grading and recording attendance for students. The systems may integrate with other systems or have modules to support other functions such as food service, transportation, assessment results, parent portals, employee information and compliance reporting. Traditionally, they were not designed to provide learning management functions or an online workspace for students, however, some products on the market blur the lines by combining LMS and SIS/SMS features. An important role of the SIS/SMS entails serving as the system of record for class rosters and as the system of record for grades. Most institutions capture CBE-based assessment results in their LMS gradebook. LMS to SIS grade reporting has been a common feature available in a standard way through IMS's LIS and the SIF 3x, but LIS does not support competencies and course-competency relationships. IMS is developing a data model for this in collaboration with the CBE-Network.

Class Rosters

In current implementations, student-centered learning is most often managed within the context of a course. Course information includes subject matter, title, description, competencies, and planned learning experiences and assessments. A student is enrolled into a section of the course (Course Section), with one or more teacher/staff assigned, and usually with beginning and ending dates. Some institutions provide "courses" that are a multi-year content stand chunked with an associated set of competencies.

The Course Section data is an important part of the administration of teaching and learning, and it's the next layer of support for student-centered learning. The Course Section data is used to produce rosters used for administration, to establish accountability and to control security of student data (i.e., a teacher assigned to the course section in which a student is enrolled may see data for that student that other teachers cannot).

The authoritative source for roster data is usually a student information system, although learning management systems may be used to manage this information. Changes in the source system need to be reflected in other system components that depend on accurate and up-to-date rosters in order to manage access to services and content.

Standards for moving class rosters data to system components include:

- OneRoster™ from IMS Global (https://www.imsglobal.org/lis/index.html)
- SIF xPress Roster from SIFA/A4L (https://www.a4l.org/Simple/Pages/default.aspx)

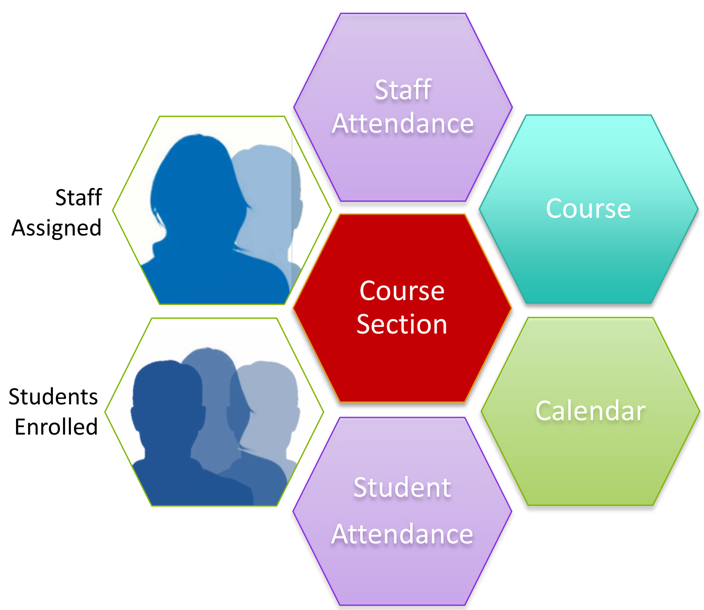


Figure 49. Data Linked through a Traditional Course-section Model

Attendance Data

Online/blended anywhere, anytime learning goes beyond "seat time." However, state and local policies still require an accounting of seat time. For example, some states require a minimum number of days (or hours) of attendance for a student to complete a grade level. Chronic absence metrics calculated from attendance data are an important at-risk indicator. Furthermore, the attendance data collection process is valuable for timely validation of class roster information. The SCL IS should allow teachers to enter attendance information once, having that data populated for all systems that need it.

The attendance entry process should allow an educator to note exceptions to the roster (e.g., if a new student attends the class but is not shown in the roster) and support a process to correct roster errors. Accurate and up-to-date roster data is needed for single sign-on and authorized access to the SCL IS.

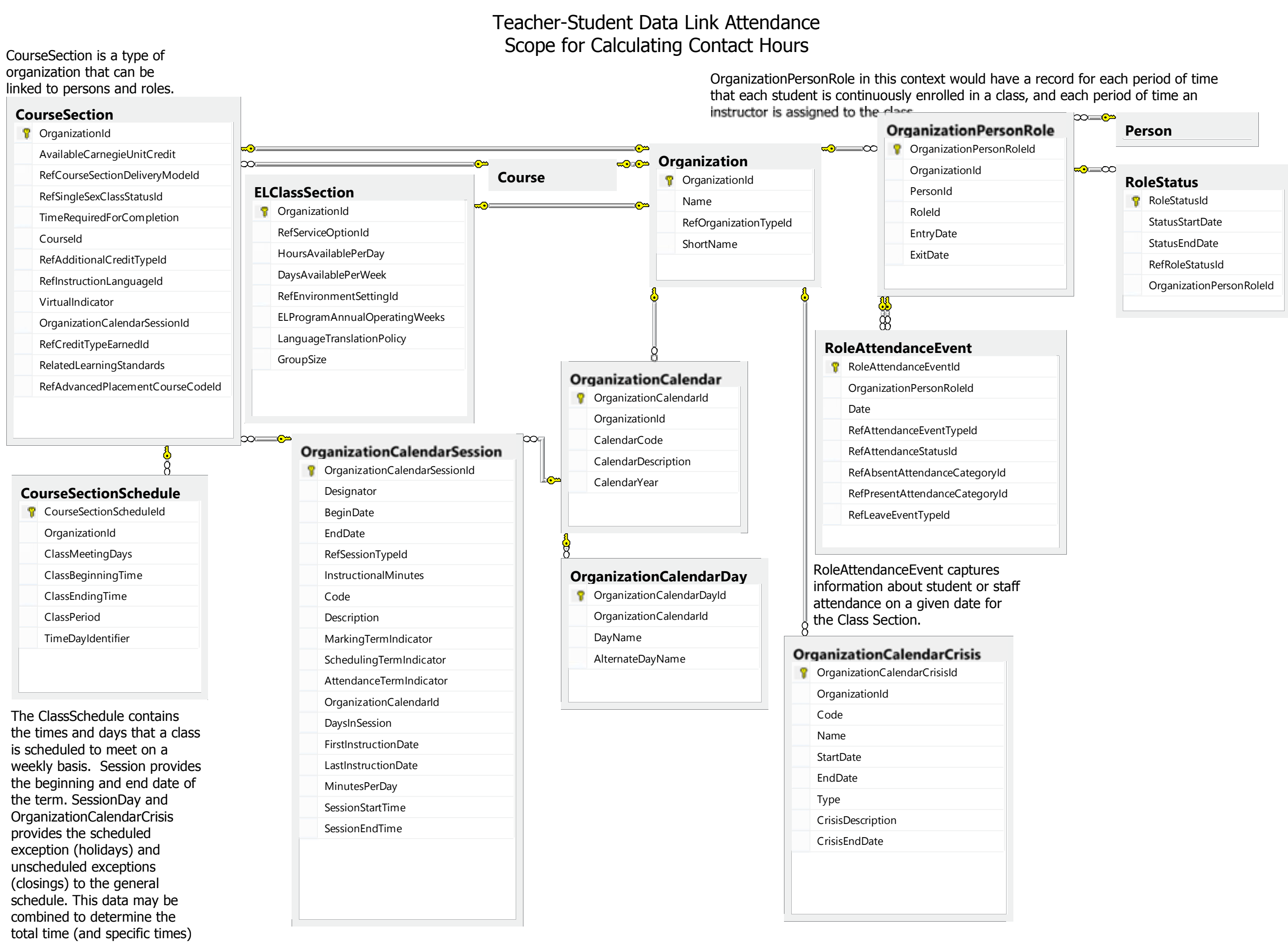


Figure 50. CEDS Reference Model Showing Attendance Data in a Normalized Data Schema

Future considerations: Some virtual schools are using a combination of manually entered attendance data and automated activity logging to estimate online and offline learning time for early warning systems and to comply with legacy policies.

Curriculum Authoring and Management Systems

Student-centered curriculum management involves developing adaptive and/or modularized content, aligning that content to standards and providing central support for development and analysis, such as looking for curriculum gaps and identifying areas of the curriculum that students seem to struggle with and why.

Student-centered curriculum management leaves behind artifacts like pacing guides and fixed curriculum maps that have a predefined sequence of learning activities. Only the learning objectives are fixed; the curriculum is adaptive and modularized.

Components of the student-centered curriculum management systems may include the following:

» adaptive content authoring tools (e.g., SmartSparrow™)
» competency mapping
» alignment tools
» content management tools (interface to a content repository, metadata tagging)
» content packaging (SCORM, CommonCartridge)
» content repository
» experience and outcomes data (such as xAPI and Caliper Analytics™)
» analytics engine
» curriculum gap analysis tools
» learning activity and outcome analysis tools

Some of these components are also part of the delivery of student-centered learning as detailed previously.

Authoring adaptive content can take several forms, depending on the subject matter and how the content will adapt. Modularized content provides a basic approach; more complex approaches allow for the learner experience within each content package to be different based on learner characteristics or actions.

The content may be "adaptive" if it has the following characteristics:

» supports UDL - adjusts the user experience for accessibility or based on a personal need or preference (e.g., text to speech for visually impaired)
» provides more than one user experience based on what the learner does or has done (e.g., spend more time on an activity if remediation is needed and a faster path if the learner has already shown mastery)
» provides feedback based on the learner's interaction with the content (hints, scaffolding prompts, encouragement, etc.)
» adjusts the difficulty level based on the learner
» adjusts the experience based on learner motivations and preferences

One kind of adaptive content is the intelligent tutor, which typically involves the learner attempting to solve a multi-step problem and the system responding to what the learner does at each step. Content for an example-tracing tutor is developed one problem at a time.

> "To develop an example-tracing tutor, the author starts by creating the student interface, followed by demonstrating correct and incorrect actions to be taken during problem solving. All actions performed by the author are visualized in the form of a behavior graph. The author annotates the graph by adding hint messages to correct links and 'buggy' messages to incorrect links. The author must also add labels to the links representing the skill behind each problem-solving step." (http://iaied.org/pub/1150/file/Mitrovic_19_2.pdf)

Some adaptive content may be developed by a teacher or group of teachers (e.g., an example-tracing problem in ASSISTments or SmartSparrow learning paths); other content requires a specialized team of subject-matter experts, instructional designers, software developers and graphic artists (e.g., simulations and content model-based tutors).

Adaptive content authoring tools tend to focus on one kind of adaptability at a time (e.g., accessibility, intelligent tutoring or preference-based) and often on one kind of content, such as mathematics problems. TheSLC IS therefore must support multiple authoring tools.

Adaptive Assessments

Adaptive assessments "are designed to adjust their level of difficulty—based on the responses provided—to match the knowledge and ability of a test taker. If a student gives a wrong answer, the computer follows up with an easier question; if the student answers correctly, the next question will be more difficult." (http://edglossary.org/computer-adaptive-test/)

The technology is often applied to interim and summative assessments to measure student progress during or at the conclusion of a specific instructional period. Unlike the intelligent tutor, which adapts the learner within the context of a given problem, the adaptive assessment adapts between problems, drawing from a large pool of assessment items. Adaptive summative assessments, unlike adaptive learning technologies, don't necessarily provide recommendations for remediation of weaknesses or formative feedback to the learner. However, the same technology could be used to better assess mastery as input to an adaptive learning recommendation engine.

Decision-Making Systems

> "Planning and advising systems create shared ownership for educational progress by providing students, faculty, and staff with holistic information and services that contribute to [student outcomes]." Ronald Yanosky, Integrated Planning and Advising Services: A Benchmarking Study, research report (Louisville, CO: ECAR), March 4, 2014.

The role that teachers and other education professionals serve to ensure that learning for each student is optimized can be supported by the right front-end decision support systems. This category of system components includes dashboards and early warning systems.

Teacher Dashboards

Teacher dashboards that support student-centered learning provide actionable data that help the teacher optimize learning for each student. For example, dashboards:

let the teacher know which students succeeded or struggled with last night's homework;

» help determine flexible grouping for project-based learning activities;

» give clues about the level of effort, engagement, etc.; and

» help prioritize the help offered to students in a class.

Administrator Dashboards

In addition to supporting decisions related to the business of running a school, administrative dashboards support oversight and supervision of teaching and learning. For example, dashboards:

alert a principal or learning coach about at-risk students;

» help determine flexible staff assignments to optimize support for student learning;

» indicate common student-centered strategies and resources that have been most successful; and

» help prioritize the programs and student support services offered across a grade-level or school.

Early Warning Systems

Early warning systems are the engines that work behind the scenes to analyze data. Conditions in the data trigger alerts that are routed to students, parents, teachers and other staff. The alerts may show up in a dashboard or as a text or email message.

DATA FLOWS

> "There are three kinds of learner data: dispositional (e.g., incoming GPA, biographic and demographic data), course activity and engagement, (e.g., keystrokes, selections, time on task) and learner artifacts (e.g., essays, blog posts, media products)." (http://net.educause.edu/ir/library/pdf/eli3035.pdf)

The SCL IS shows the inclusion of each of these kinds of data in the overall system design.

Cloud Based Technologies

LEAs and schools increasingly rely on hosted applications rather than trying to build and maintain the infrastructure to host software internally. This may be the only option for small agencies with limited IT staffs and budgets. LEAs and schools may contract directly with commercial vendors or subscribe to services through their state or a regional education service agency.

The complete SCL IS may be accomplished by integrating a number of hosted services. The number of hosted applications required depends on how functionality is bundled within applications.

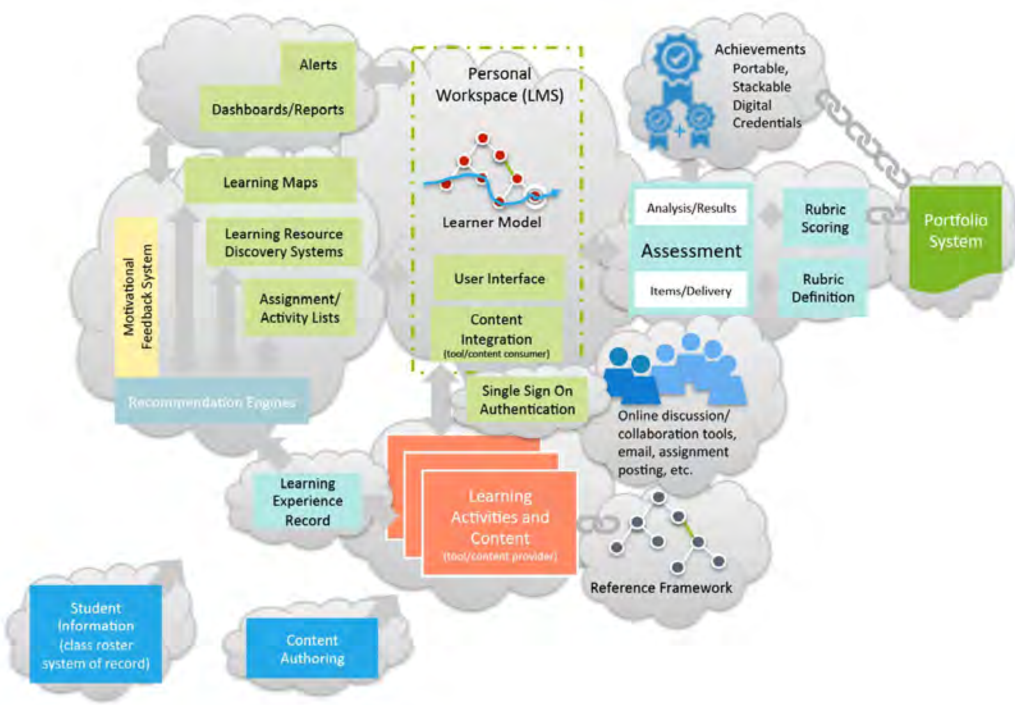


Figure 51. Example of Integrated Hosted Applications

Enterprise Data Systems

Large school districts and state education agencies often depend on enterprise systems for data warehousing and master data management. Data warehouse technology supports ad hoc analytics for very large data sets spanning years and millions of records. Master data management technology allows organizations to provide a single point of reference for critical operational data.

Until recently, K12 enterprise data systems have emphasized the data used for administration and accountability. The data collected have been useful for managing organizational processes and tracking outcomes for disaggregated groups and cohorts of students. These systems typically use a relational database with a structure optimized either for collection or reporting/analysis. Systems for student-centered learning introduce new kinds of data into the existing pipeline, such as experience data and outputs from recommendation engines.

Some of the data and content for student-centered learning do not fit directly into data stores designed for administration, accountability and decision support.

For example, the Learning Record Store (IMS Caliper: "Analytics Store") that captures learning transactions and "click stream" data is kept separate from other operational data, but the analysis of that data by a recommendation engine can become the derived data needed to keep the learner specific model up-to-date in an operational data store.

Content repositories and student portfolio systems also rely on data stores that are technically different than most other operational data systems. The SCL IS makes use of Internet protocols to connect these disparate sources, i.e., a URL stored in a relational database can be the link to an item in a learning object repository or portfolio system.

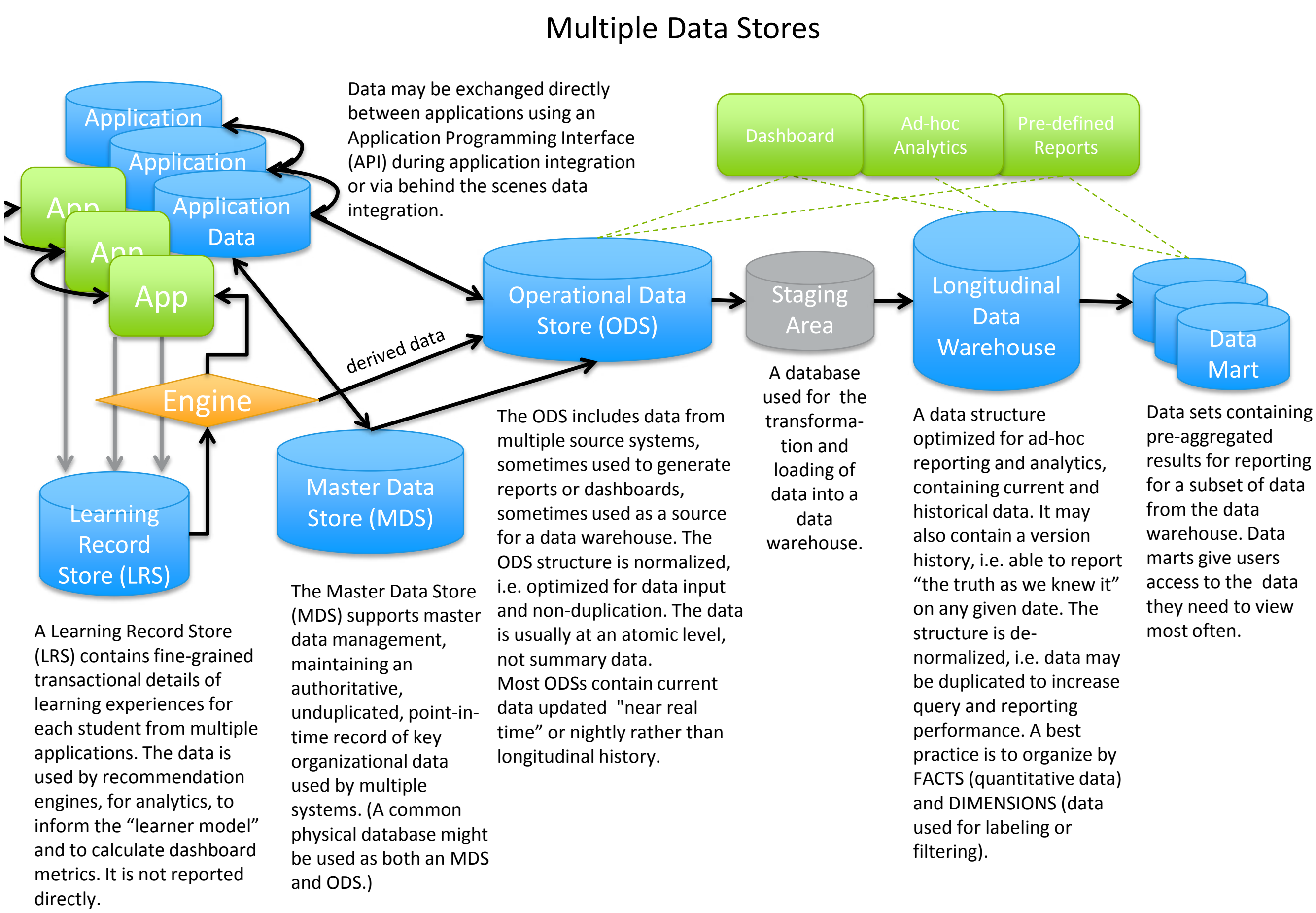


Figure 52. Multiple Data Stores

Appendix C: Glossary

Competency Education

The five-part working definition of competency education describes the elements that need to be put into place to re-engineer the education system to reliably produce student learning:

» Students advance upon demonstrated mastery;
» Competencies include explicit, measurable, transferable learning objectives that empower students;
» Assessment is meaningful and a positive learning experience for students; students receive timely, differentiated support based on their individual learning needs; and
» Learning outcomes emphasize competencies that include application and creation of knowledge along with the development of important skills and dispositions.[19]

Deeper Learning

"Deeper learning is an umbrella term for the skills and knowledge that students must possess to succeed in 21st century jobs and civic life. At its heart is a set of competencies students must master in order to develop a keen understanding of academic content and apply their knowledge to problems in the classroom and on the job. The deeper learning framework includes six competencies that are essential to prepare students to achieve at high levels.

Competencies

» Master core academic content
» Think critically and solve complex problems
» Work collaboratively
» Communicate effectively
» Learn how to learn
» Develop academic mindsets

The foundation of deeper learning is mastery of core academic content, whether in traditional subjects such as mathematics or in interdisciplinary fields which merge several key fields of study.

Students are expected to be active participants in their education. Ideally, they are immersed in a challenging curriculum that requires them to seek out and acquire new knowledge, apply what they have learned, and build upon that to create new knowledge."[20]

Education Data and Interoperability Standards

» **CCSS**: Common Core State Standards - http://www.corestandards.org/developers-and-publishers/
» **CEDS**: Common Education Data Standards - http://ceds.ed.gov/
» **Ed-Fi:** Ed-Fi Alliance - http://www.ed-fi.org/
» **EDI:** Electronic Data Interchange - http://en.wikipedia.org/wiki/Electronic_data_interchange

19. (Detailed) definition: "Competency Education." competencyworks.pbworks.com. http://competencyworks.pbworks.com/w/page/67945372/Detailed%2520Definition%2520of%2520Competency%2520Education
20. Deeper Learning Defined, 04/23/2013 http://www.hewlett.org/uploads/documents/Deeper_Learning_Defined__April_2013.pdf

- **ESB:** Enterprise Service Bus - http://en.wikipedia.org/wiki/Enterprise_service_bus
- **IMS CC:** IMS Common Cartridge- http://www.imsglobal.org/cc/
- **IMS LTI:** IMS Learning Tools Interoperability - http://www.imsglobal.org/lti/
- **IMS QTI:** IMS Question and Test Interoperability - http://www.imsglobal.org/question/
- **IMS Caliper Analytics™**: http://www.imsglobal.org/activity/caliperram
- **LR:** Learning Registry - http://learningregistry.org/
- **LRMI:** Learning Resource Metadata Initiative - http://www.lrmi.net/
- **NGSS:** Next Generation Science Standards - http://www.nextgenscience.org/
- **OAI-PMH:** Open Archives Initiative – Protocol for Metadata Harvesting - http://www.openarchives.org/pmh/
- **OBI:** Open Badge Infrastructure - http://openbadges.org/
- **PESC:** Postsecondary Electronic Standards Council - http://www.pesc.org/
- **REST:** Representational State Transfer - http://en.wikipedia.org/wiki/Representational_state_transfer
- **SEED:** State Exchange of Education Data - http://www.ncpublicschools.org/data/seed/
- **SIF:** SIF Association - http://www.sifassociation.org
- **SOAP:** Simple Object Access Protocol - http://en.wikipedia.org/wiki/SOAP
- **xAPI:** Experience API - http://www.adlnet.gov/tla/experience-api/

Metadata

Information about a digital object, enabling it to be retrieved from a database. It may be located separately from the resource it describes or embedded within that resource.

Meta tag

The <meta> tag provides metadata about the digital object. Meta tag can also be used as a verb to indicate the process of adding metadata.

Learning Maps

Learning maps help learners see the bigger picture. Learning maps show where the student is and where the student is going. The organization will need to define what it wants the learning map to include and display.

Learner Profile

The purpose of this capability is to integrate all relevant points of information related to students into comprehensive portraits of each student, including his or her achievement data, strengths, needs, interests, ways he or she learns best and preferences—making this accessible to users and stakeholders. It combines data from source systems and input from students, parents, educators and others who work with the student. It also could include learner specific misconceptions, habitual mistakes or exemplary practices related to learning outcomes.

Personal Learning Plan

An academic-planning document created by students under the guidance of a teacher, advisor or other trusted adult. Personal learning plans come in many forms, but they typically evolve over time and include individual educational aspirations and goals, as well as personal learning strengths and weaknesses, among other features.

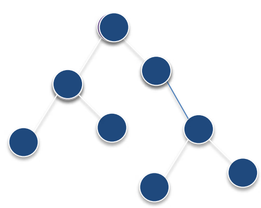
The personalized learning plan pulls the competencies, learning outcomes and sequencing (if any) from the reference frameworks.

Portfolio

A portfolio is a collection of student work, reflections and assorted evidence that represents mastery of competencies. It becomes a personalized method of archiving a student's educational experience and documents growth over time. It can be used as a communication tool regarding learning.

Reference Framework

The reference framework defines what a learner should know or be able to do and defines rules for measures that indicate levels of mastery.



Reference Framework

The reference framework will often be based on learning standards adopted by the jurisdiction (e.g., state or local school district). It may also include standards for habits of learning and indicators for 21st Century Skills. It may include additional information about how to measure levels of mastery, more granular competencies (such as process steps that make up a skill) and relationships between individual competencies (e.g., prerequisite/post-requisite relationships).

Reference frameworks are typically defined as a hierarchy of statements with the subject matter context at the top (e.g., Mathematics), one or more levels of classifying statements (e.g., Number and Operations), and one or more levels of competency definitions. They may include recommended and alternative competency pathways.

Social Bookmarking

Social bookmarking is a way for people to store, organize, search and manage "bookmarks" of Web pages. Users save links to Web pages that they like or want to share, using a social bookmarking site to store these links. Users can add, annotate, edit and share bookmarks of Web documents. "Most social bookmark services are organized by users applying "tags" or keywords to content on a website. This means that other users can view bookmarks that are associated with a chosen tag and see information about the number of users who have bookmarked them. In many cases, users can also comment or vote on bookmarked items.

Standard

A standard describes what students should know and be able to do. Different states and districts use learning targets, assessment targets, measurement topics and competencies to describe standards, groups of standards or standards that have been reframed into language more reflective of application and use.[21]

UDL

Universal design for learning (UDL) is a framework to improve and optimize teaching and learning for all people, based on scientific insights into how humans learn.

21. "Advancing Competency-Based Pathways to College and Career Readiness: A State Policy Framework for Graduation Requirements, Assessment and Accountability." Achieve. http://www.achieve.org/files/13-195%20Achieve_CBP_07018.pdf

Acknowledgments

Appendix A

A very special thank you to Brandt Redd for writing Appendix A: Understanding Education Technology Standards. Brandt is currently the Chief Technology Officer of the Smarter Balanced Assessment Consortium, former Senior Technology Officer, U.S. Program for the Bill and Melinda Gates Foundation and former Chief Technology Office for Agilix Labs, Inc.

Review Group

In addition, we extend our thanks and deep appreciation to the Review Group of leading educators, technology innovators and researchers who reviewed drafts of the guide and provided invaluable feedback, writing and examples from their experiences.

- Antonia Rudenstine, redesign, Principal Consultant
- Bob Cole, Howard County Public Schools, Coordinator of Digital Education
- Brandt Redd , Smarter Balance, Chief Information Officer / CTO
- Chris Sturgis, CompetencyWorks, MetisNet
- David Irwin, Gartner Inc. Managing Partner, K-12 Education Practice Lead
- Larry L Fruth II, Access 4 Learning Community (formerly SIFA), Executive Director / CEO
- L. Beatrice Arnillas, Houston Independent School District, Texas, Director, IT - Education Technology
- Myk Garn, Board of Regents of University System of Georgia, Assistant Vice Chancellor for New Learning Models and Board Member of the Competency-Based Education Network
- Nancy Wilson, Collaboration Synergy, CEO
- Rick Rozzelle, CELT, President and CIO
- Rose Colby, Competency-Based Learning and Assessment Specialist
- Rob Abel, IMS Global Learning Consortium, Chief Executive Officer
- Sarena E. Sacks, Fulton Public Schools, Georgia, CIO Office of Information Technology
- Scott Ellis, Learning Accelerator, CEO
- Scott Muri, Spring Branch Independent School District, Texas, Superintendent of Schools
- Susan Patrick, iNACOL
- Thomas Arnett, Christensen Institute, Research Fellow, Education
- Vic Vuchic, Digital Promise

Additional Acknowledgements

We wish to thank all of the people and organizations listed here. These extraordinary educators bring to their work creativity, a deep commitment to our children and a love of learning. Without their generosity in sharing their knowledge, this paper would simply not be possible.

- Agilix - Buzz
- Al Motley, Matchbook Learning
- Alex Jackl, Bardic Systems
- Alison Hramiec, Andrea Kunst Boston Day and Night Academy

- Amy Jenkins, EdElements
- Andy Calkins, EDUCAUSE, Next Generation Learning Challenges
- Antonia Rudenstine, ReDesign
- Aveson Charter Schools, Altadena, California
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- Betsy Corcoran, EdSurge
- Bob Cole, Howard County Public Schools
- Brandt Redd, Smarter Balance
- Bryan Setser, Matchbook Learning
- Catherine Allshouse, KnowledgeWorks
- Chris Liang-Vergara, Leap Innovations
- Chris Sturgis, Competency Works and MetisNet
- Connie Maggert and Amy Barger, Fulton Public Schools, Georgia
- David Wiley, Lumen Learning
- Denver Public Schools
- Don Walsh and Terri-Lynn Brown, Brightspace and LeaP -Desire2Learn
- Echo
- Edsby
- Emily Dalton Smith, Facebook
- Fishtree
- Garfield Elementary School, Oakland Unified School District
- George Scotti and team, itslearning
- Greg Klein, Roger Foundation
- Henry County Schools ,Georgia
- Henry Hipps and Adam Goldfarb, Bill and Melinda Gates Foundation
- Howard Lurie, Acrobatiq - A Carnegie Mellon University Venture
- Infinite Campus
- Jennifer Whiting, Florida Virtual School
- Kate Gallagher, Blackboard
- Keith R. Krueger, The Consortium for School Networking
- Kim Carter, QED Foundation
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- Scott Bacon and John A. Caesar, Educate-Empower, 3 Shapes LLC
- Scott Ellis and Beth Rabit, Learning Accelerator
- Scott Welch, Edsby
- Show Evidence
- Stacey Wang and Tracey, Oakland Unified School District
- Summit Denali, Oakland
- Susan Patrick, Bruce Friend, Natalie Abel, iNACOL
- The Colorado Education Initiative
- Tom Vander Ark, Getting Smart
- Tracy Dalton, Calgary Board of Education
- Vic Vuchic, Digital Promise
- Virgil Hammonds, Maine RU2 former Superintendent, now Chief Learning Officer at KnowledgeWorks
- Wendy Riedy, PerformancePlus

We want to give a special thank you to the Nellie Mae Education Foundation. We are grateful for their support of this report and their collaborative commitment for identifying infrastructure needs for student-centered learning systems. There are times when philanthropic leadership is invaluable in helping our country take innovative leaps. With the greatest appreciation, we want to thank the Nellie Mae Education Foundation for their investments to support student-centered learning. The Nellie Mae Education Foundation's pioneering spirit and drive for creative problem-solving and new designs exemplify the qualities that we want our children to have to be able to adapt to the global challenges before us.

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