

LITERATURE & TOOL REVIEW



*Measuring and Improving
Student-Centered Learning Toolkit*

DEFINING AND MEASURING STUDENT-CENTERED LEARNING

An Overview of Research Literature and Data Collection Tools

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PREFACE

This project and report are funded by the Nellie Mae Education Foundation (NMEF), the largest philanthropy in New England devoted completely to education. A key focus of NMEF's work with high schools is to implement a vision of student-centered learning (SCL) that focuses on the following four tenets: (1) learning is personalized; (2) learning is competency-based; (3) learning occurs anytime, anywhere; and (4) learning is engaging. One way for NMEF to monitor and better understand the impact of its work is to develop data collection instruments that can measure the extent to which schools are implementing their vision of SCL. RAND Education, a unit of the RAND Corporation, is working with NMEF to develop these instruments.

This report lays the groundwork for the development of these instruments to measure SCL through a conceptual framework that presents five key SCL strategies and the baseline conditions that support SCL implementation. The report examines the research literature that studies the relationship between the strategies and conditions in the framework and relevant student outcomes, describes existing data collection instruments for measuring SCL, and serves as a foundation for the Toolkit we developed.

Measuring and Improving Student-Centered Learning Toolkit

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EXECUTIVE SUMMARY

The purpose of this review is to lay the groundwork for the development of a set of instruments—or a “tool”—to gauge the extent of Student-Centered Learning (SCL) practices, and supports for those practices, in classrooms and schools. As such, this report (1) presents a conceptual framework including key strategies and contextual conditions that support SCL, based on a review of the SCL literature and feedback from expert advisors; (2) reviews relevant research on those strategies and conditions, including studies demonstrating a relationship between strategies, conditions, and positive student outcomes (i.e., academic performance and student engagement); and (3) reviews existing instruments for measuring SCL and the advantages and drawbacks of these instruments.

The following definition of SCL guides our conceptual framework: *SCL is students' deep engagement in learning opportunities that are designed to address their goals and interests while at the same time providing appropriate supports and challenge according to their learning needs.* Based on this definition, our conceptual framework focuses on five SCL strategies that involve both educators and students:

1. Learning is personalized to align with students' needs, interests, and pace.
2. Learning is challenging, engaging, and meets students where they are in a competency-based system.
3. Learning happens anytime, anywhere.
4. Learning opportunities promote student agency and ownership.
5. Learning is informed by data.

Although our literature review found some evidence of the effectiveness of some large-scale SCL interventions, other studies suggest that the effectiveness of SCL, writ-large, is mixed. The studies we reviewed also noted that SCL can be implemented in a wide variety of ways,

and not all SCL programs include the five key strategies discussed above. However, we also found that there do seem to be some SCL practices associated with the strategies we highlighted above that have a stronger empirical basis than others, including:

- Personalization of content based on student interests
- Competency- and mastery-based systems in which students have unlimited time to master specific learning targets or goals before moving on to new goals
- Service learning programs linking community service to classroom instruction
- Teaching metacognitive strategies that help students plan and monitor their own learning

While we identified some research indicating that these practices can help improve students' academic achievement and engagement, the research also notes high variability in implementation of SCL practices. That variability may be responsible for mixed results in some settings. Thus, specific implementation features, choices, and context surrounding these practices may matter a great deal for the success of particular SCL programs.

Additionally, given that most SCL strategies represent a considerable shift from traditional approaches to schooling, the contextual "conditions" for SCL programs are likely important aspects of successful SCL program implementation. The key contextual conditions for implementation of SCL approaches, and similarly ambitious reforms, include committed leadership; a comprehensive, shared vision for reform; active partnerships with other stakeholders; a comprehensive, long-term adult learning plan; alignment among vision, policy, tools, and professional development within the school system; and a commitment to quality assurance and continuous improvement (e.g., Coburn, 2003; Stein and Spillane, 2005; Cobb and Smith, 2008). In addition, SCL reforms often require thoughtful and high-quality technological infrastructure and platforms to support online and digital learning. Research also suggests that contextual classroom learning conditions most likely to support SCL are those in which students perceive teachers to be respectful, caring, and supportive (e.g., Ryan, Stiller, and Lynch, 1994).

We identified about 100 existing data collection instruments that address the SCL strategies and conditions outlined in our conceptual framework. Half of the instruments we identified were surveys, although we also found a wide range of other instruments used to measure SCL, including interview protocols, practice guides, and observation and artifact rubrics, among others. Competency-based learning and student agency were among the most common SCL constructs measured by the existing instruments included in our review.

Our tool review identified a number of points for reflection and challenges related to measuring SCL. For example, the choice of developing any particular instrument to measure SCL represents some tradeoffs. For example, surveys are an efficient way to measure SCL

across a school system and multiple stakeholders, but the response biases associated with surveys are well-documented. On the other hand, observations and rubrics to gauge the quality of artifacts like student work can provide a rich illustration of practice but can also represent considerable burden in terms of the time to train data collectors, collect the data, and analyze it. Other challenges specific to the measurement of SCL include the difficulty of capturing the important—and often intentional—variations in SCL practices, and the need to measure SCL implementation at many different grain sizes, as well as learning that occurs outside the classroom and school day, or through online software platforms.

This literature and tool review served as the basis for the development of a tool intended to be used by researchers and practitioners to measure the extent of SCL implementation in classrooms and schools. We hope that the [User Guide](#), [Instruments](#), and [Reflection Tools](#) that were developed, based on this review, can help district and school systems consider what aspects of SCL they intend to emphasize and measure, and provide rich data on the extent of SCL implementation in schools and classrooms.

SECTION 1

INTRODUCTION

“Student-centered learning” (SCL) can describe a wide array of strategies and approaches within the research literature (Scheopner Torres, Brett, and Cox, 2015). Some of the phrases that researchers and practitioners have associated with SCL most recently have ranged from “personalization” and “differentiation” to “case-based learning,” “problem-based learning,” “competency-based learning,” “inquiry-based learning,” “discovery learning,” and many more. Over the past decade, more attention has been focused on the use of technology to enhance or support SCL and SCL “environments” (Hannafin, Hill, and Land, 1997; Hannafin and Land, 1997; Brush and Saye, 2000). But even that literature varies in how it defines SCL implementation and supports.

We define SCL as *students' deep engagement in learning opportunities that are designed to address their goals and interests while at the same time providing appropriate supports and challenges according to their learning needs*. This definition is derived from research literature on SCL, and it also draws on the vision of SCL embraced by the Nellie Mae Education Foundation (NMEF). NMEF's vision for SCL specifically notes that: (1) learning is personalized; (2) learning is competency-based; (3) learning takes place anytime, anywhere; and (4) students exert ownership over their learning. Studies of SCL suggest that students' exposure to this and similar visions of instruction can vary extensively, and implementation can present considerable challenges. As RAND found in a recent study of schools implementing personalized learning (Pane et al., 2015), some schools used technology-based curricula to offer each student an individualized curriculum. However, often this occurred in only some subjects, and in many cases there were constraints on the extent of personalization. Tailoring instruction to students' interests was particularly challenging, in part due to a lack of appropriate instructional materials. Similarly, in schools that supported learning outside of the school day and the school building, limitations in technology availability and lack of instructional support sometimes led to low usage (Pane et al., 2015).

Recent RAND research also suggests that competency-based progressions that are often part of SCL initiatives can be limited by lack of high-quality assessments to gauge competency and by inadequate curriculum materials to facilitate student advancement, in addition to policy barriers (e.g., seat-time requirements). Moreover, teachers sometimes take an approach to competency-based progression that focuses more on completion (e.g., percentage of problems solved) than on mastery of the material (Pane et al., 2017b; Steiner et al., 2017).

These differences in the interpretation of SCL and its implementation can result in inequitable opportunities for students. Recent RAND research on competency-based education, for instance, noted educators' concern that variation in pace could lead to an increase rather

than a decrease in performance gaps, and some students could have more opportunities than others to pursue anytime/anywhere learning opportunities (Steele et al., 2014). Equitable opportunities require teachers not only to offer all students a rigorous instructional program, but also necessitate their attention to students' social and emotional skills such as persistence and motivation, which can strongly influence how students respond to student-centered approaches (Lewis et al., 2014).

To date, several studies have gathered data on key features of SCL in classrooms and schools, including tools developed for the RAND study of personalized learning in Next Generation Learning Challenge (NGLC) schools (Pane et al., 2015); evaluations of "deeper learning" in schools (e.g., Bitter et al., 2014; Huberman et al., 2014; Zeiser et al., 2014; Heller and Wolfe, 2015; Huberman et al., 2016); an investigation of competency-based learning practices (Ryan and Cox, 2017); a study of four California schools participating in the Linked Learning or Envision Education models (Friedlaender et al., 2014); and numerous case studies of SCL practices in schools (e.g., Wolfe, 2012; Bertrand, Allen, and Steinberg, 2013). These studies have relied on instruments that include surveys, logs, interviews, classroom artifacts, and observations to document the prevalence of SCL practices. These instruments provide a useful starting point for the development of instruments that encompass all the elements of SCL included in NMEF's vision. But none are currently appropriate for measuring the prevalence of the full range of SCL practices across a school system, including multiple classrooms and schools.

Purpose of This Report

The purpose of this report is to lay the groundwork for development of a set of instruments—or a "tool"—to gauge the extent of SCL practices, and supports for those practices, in classrooms and schools. Guided by our definition of SCL, our review of relevant literature, and our consultation with experts, we propose a set of *key strategies* that could promote SCL practices and signal the extent of SCL practices in classrooms and schools. We also propose a set of *contextual conditions* that might support high-quality implementation of those strategies. These strategies and conditions informed both the [instruments](#) included in the tool, and also the aspects of SCL that we attempt to measure using that tool. The SCL strategies we propose are:

1. Learning is personalized to align with students' needs, interests, and pace.
2. Learning is challenging, engaging, and meets students where they are in a competency-based system.
3. Learning happens anytime, anywhere.
4. Learning opportunities promote student agency and ownership.
5. Learning is informed by data.

These strategies are not the only way to promote or measure the presence of SCL, nor do we think that all the strategies and contextual conditions we propose are necessary for teachers, students, schools, or school systems to engage in SCL. Instead, we present these ideas as a conceptual framework to guide the development of one possible set of instruments to measure implementation of SCL, drawing upon lessons from our own research, other research literature on SCL, feedback from researchers and educators, and the considerable work on SCL that has already been completed by and with support from NMEF.

Ideally, the set of instruments we developed will support work at NMEF to understand whether their investment in particular aspects of SCL has resulted in measurable changes within districts and schools. Our aim is that the instruments we develop can support the work of educators and researchers to reflect upon the aspects of SCL that they would like to measure, implement, and improve within their own contexts.

Organization of This Report

We begin this appendix with a brief description of the methods we used for our literature and tool reviews. We then lay out the conceptual framework we use to define and measure SCL. The conceptual framework is informed by NMEF's vision, the research literature, and engagement with experts (including practitioners) on SCL, education, and the measurement of instruction. Next, we describe the research base linking each element of that framework to student outcomes, where such evidence exists. We then present the results of our tool review, discussing the measures that currently exist for measuring SCL. Lastly, we describe our next steps for tool development. A list of the instruments in our review is provided in the appendix.

SECTION 2

METHODS FOR LITERATURE AND TOOL REVIEW

A primary goal of our literature review was to identify key and mutually exclusive SCL strategies—and the contextual, or system, conditions that could support those strategies—in order to guide the development of a set of instruments—a tool—for measuring SCL in classrooms and schools. Another goal was to identify existing instruments for measuring SCL that could support instrument development in this study. In this section, we describe our literature review process and our process for seeking feedback from experts to guide our work. We also discuss the review of existing instruments for measuring SCL that we conducted in tandem with our literature review.

The NMEF tenets served as a starting point for our literature review: (1) learning is personalized; (2) learning is competency-based; (3) learning takes place anytime, anywhere; and (4) students exert ownership over their learning. Given that these tenets are broad and related to a wide variety of research studies and measures, we did not do a comprehensive review of all research related to SCL. Instead, we prioritized descriptive studies that could give us a sense of how these tenets are implemented in schools and empirical studies that link implementation of these tenets with academic and socio-emotional student outcomes (e.g., achievement, grades, graduation, self-regulation, interest in school, engagement). We included studies that examined implementation of SCL at the classroom level, as well as studies that discussed the system-level factors—at the district/charter management organization or school level—that can support classroom-level SCL practices. To conduct searches of available literature and instruments, we reviewed NMEF’s existing catalog of resources on SCL, as well as other recent reviews of literature on SCL. We also reviewed the websites of organizations (e.g., research firms, foundations, technical assistance providers) that focus on SCL, conducted searches using Google Scholar, and solicited suggestions from our advisory board members. We prioritized studies that were published after 1990 with a handful of exceptions for literature that we regarded as seminal or which was often cited by other sources. We reviewed roughly 225 studies, excluding websites and blog posts that also provided some context and information for our work.

In concert with our literature review, we searched for and reviewed instruments that were designed to measure the extent of SCL implementation. If a research article on SCL also provided information on specific instruments used to measure SCL (e.g., provided survey items or named an instrument), we checked to see if the entire instrument was available within the research article or elsewhere. If it was available, we documented the name and/or URL link to the instrument; topics addressed within the instrument; and any information on the reliability or validity evidence that had been gathered for the instrument. All of the

references cited in this review are listed at the end of this report, and our catalogue of instruments can be found in the appendix.

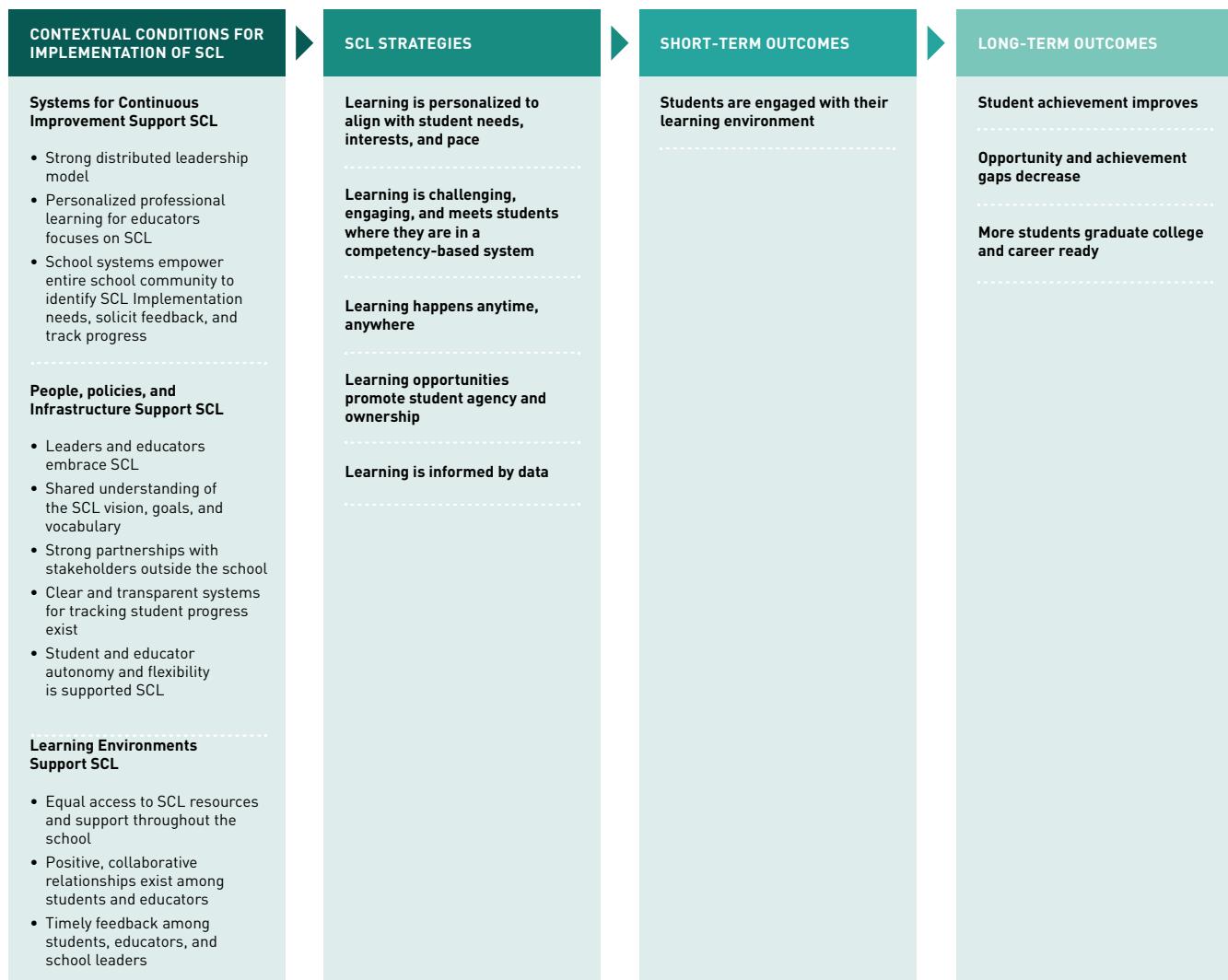
We used the initial findings from our review of literature and tools to develop a preliminary conceptual framework depicting the key strategies and supports for SCL. We then met with our advisory board members to present our framework. The advisory board included practitioners and researchers with expertise in measuring or implementing SCL. NMEF staff also provided input on our framework through regular phone meetings and the advisory board meeting. We used the feedback to make revisions to our approach and framework. In the next section, we provide an overview of our conceptual framework for defining and measuring SCL.

SECTION 3

A FRAMEWORK FOR DEFINING AND MEASURING STUDENT-CENTERED LEARNING

To develop measures of SCL, we needed to first develop a definition and conceptual framework for SCL grounded in the research literature that could justify a focus on particular elements of SCL. The definition was provided in Section 1. Figure 3.1 presents the conceptual framework that emerged from our literature review and consultation with experts. It includes (1) the contextual conditions that might be necessary to support SCL implementation; (2) key strategies for implementing SCL; and (3) outcomes that appear to be related to the extent of SCL implementation in classrooms and schools, based on SCL strategies in our conceptual framework.

Figure 3.1 A Conceptual Framework for Student-Centered Learning



As reflected in our conceptual framework, research suggests that students' engagement in learning is a key goal of many SCL initiatives and programs (e.g., Priest et al., 2012; Yonezawa, McClure, and Jones, 2012; Le, Wolfe, and Steinberg, 2014; Steele et al., 2014; NMEF, 2015; Pearson and Flory, 2015; Haynes et al., 2016). Much research evidence clearly ties students' engagement in their own learning to gains in achievement and other positive student outcomes, although definitions and measures of students' engagement vary. For example, measures of engagement with significant ties to achievement and other student outcomes include measures of students' "cognitive engagement," or deep engagement in cognitively demanding work (Pintrich and De Groot, 1990; Hughes et al., 2008; Greene, 2015); students' use of self-regulatory strategies to manage and monitor their own learning (Pintrich and De Groot, 1990; Wang and Holcombe, 2010); and students' participation and interest in school (Roeser, Eccles, and Sameroff, 2000; Wang and Holcombe, 2010). The strong ties between student engagement and achievement imply that students' engagement and involvement in their own learning is an important goal.

Fewer studies provide evidence that SCL strategies used by educators and schools can influence or improve students' engagement and, thus, student achievement. It is these strategies that are the main focus of our review. First, we provide a brief overview of these strategies and explanations for their inclusion in our conceptual framework. Second, we examine the research evidence supporting these strategies and instructional practices associated with them. Finally, we consider the key contextual conditions within district and school systems that might be most important for supporting implementation of those SCL strategies.

An Overview of the Five SCL Strategies and Their Associated Practices

The SCL strategies named as part of our conceptual framework intentionally involve both educators—defined broadly as teachers and other staff that support students, as well as leaders within district and school systems—and students. The success of SCL programs depends on the deep involvement of students themselves, as well as educators working at all different levels of school systems to support those students. This deep involvement of both students and educators in SCL also has implications for the set of instruments designed to measure SCL. As we discuss in the [User Guide](#), the Measuring Student-Centered Learning Toolkit is designed as a tool that incorporates the perspectives of educators and students in order to capture the full extent of SCL learning present within school systems and classrooms.

The SCL strategies in our conceptual framework implicitly involve both students and educators. Therefore, each of the strategies can be interpreted both as an action implemented by educators and as the learning experience of students. Thus, each of the strategies implies specific practices on the part of both students and educators. Table 3.1 lists the proposed SCL

strategies alongside associated student and educator practices. The strategies and practices identified in Table 3.1 all emerged from the literature as those that are intertwined with current assumptions and ideas about what is important and essential to SCL, according to both NMEF and many recent SCL programs and initiatives. These strategies are summarized in more detail in the next several paragraphs. We then consider student outcomes related to these strategies. As we discuss, some SCL strategies and practices in our conceptual framework have a stronger empirical basis for inclusion than others.

Table 3.1 Five SCL Strategies and Related Practices

SCL Strategy	Related Practices
Strategy 1: Learning is personalized to align with students' needs, interests, and pace.	<ul style="list-style-type: none">• Educators and students work together to personalize students' pathways through content and courses• Timing and delivery of learning opportunities are varied to support students' learning needs, interests, and pace• Assessments are varied to support students' learning needs, interests, and pace
Strategy 2: Learning is challenging, engaging, and meets students where they are in a competency-based system.	<ul style="list-style-type: none">• Learning targets and pathways are clear, measurable, and competency-based• Courses, assignments, activities, materials, and assessments are aligned to competencies• Students access assessments when they are ready to demonstrate mastery and earn credit.• Learning opportunities and assessments reflect high expectations and provide appropriate challenge for each student• Students engage in meaningful, cognitively challenging assignments and activities

Strategy 3: Learning happens anytime, anywhere.	<ul style="list-style-type: none">• Students engage in multiple credit-bearing learning activities within and outside of the classroom• Students engage in authentic assignments and activities with connections to the real world
Strategy 4: Learning opportunities promote student agency and ownership.	<ul style="list-style-type: none">• Students participate in activities that promote self-regulation, collaboration, metacognition, and communication strategies• Students develop their own learning pathways and profiles with appropriate support
Strategy 5: Learning is informed by data.	<ul style="list-style-type: none">• Educators and students gather data on students' needs, interests, goals, and learning progress• Educators and students use data to inform learning pathways and monitor progress

Strategy 1: Learning is personalized to align with students' needs, interests, and pace.

In an ideal personalized learning system that is truly student-centered, every student's learning is customized to their needs, interests, and pace (Vrasidas, 2003; Patrick, Kennedy, and Powell, 2013; Pane et al., 2015). One way to do this is through learning pathways, which are the routes students take through courses, content, and tasks. At the highest level, a learning pathway could be the individualized set of courses a student would take throughout high school. At a more granular level, a personalized pathway might also detail the specific tasks students would complete within a course or unit as they prepare to demonstrate mastery of a certain skill, such as in a playlist (Cole, Kemple, and Segeritz, 2012; Miller Lieber, 2014; Ready, 2014). In addition to a personalized path through content, personalized learning pathways could afford variety in the pacing, timing, and delivery of instruction such that learning occurs outside of school as well as within school. A personalized pathway could also include a variety of modes of delivery—such as online, small group, or experiential learning—that provide multiple ways for students to engage with the content (JFF and CCSSO, undated; Rose and Gravel, 2012). Similarly, personalized learning pathways could offer multiple approaches to assessment (e.g., projects, presentations, tests) that allow students to demonstrate mastery (JFF and CCSSO, undated).

One common way students and teachers can plan multiple pathways is through the use of learner plans, or learner profiles. These plans could include information about the pacing, timing (e.g., during/outside of school, course sequences), location (e.g., within school/outside of school), mode of delivery (e.g., small group, independent research, experiential learning), timing and type of assessment, learning strategies, and competencies (Miller Lieber, 2014). Learner plans can be paper-based or digital. They can lay out the scope and sequence of a student's K-12 learning career and include goals for after high school, or more narrowly focus on the material needed to master a particular competency and the goals for the assessment. Learner plans can also help students and adults monitor their progress.

Strategy 2: Learning is challenging, engaging, and meets students where they are in a competency-based system.

In competency-based systems, which are also known as mastery-based systems, student mastery of a set of content and skills determines student progression and award of credit, rather than whether students sat through particular courses or grades. Although competency-based systems can be implemented in a number of different ways, most descriptions of such systems include the key practices shown in Table 3.1, including clear, measurable competency-based learning targets; courses, learning tasks, materials, and assessments aligned to competencies; assessments available when students are ready to demonstrate mastery; learning opportunities and assessments reflect high expectations and provide appropriate challenge for each student; and student engagement in meaningful, cognitively challenging learning tasks (Sturgis, 2012; Book, 2014; Le, Wolfe, and Steinberg, 2014; Steele et al., 2014; Domaleski, 2015; Pane et al., 2015; Scheopner Torres, Brett, and Cox, 2015). In some programs, competency-based systems are described as following a Mastery Learning Approach or MLA. The concept of "deeper learning" is also sometimes linked with competency-based learning and involves students' "ability to apply that understanding to novel problems and situations and the development of a range of competencies, including people skills and self-control" (see AIR, 2016a).

In competency-based systems, the content and skills learned are often referred to as competencies (or, alternatively, as learning targets, proficiencies, goals, or standards). Competencies must be clear and measurable so students understand what they are supposed to learn and how they will be assessed, and so teachers can accurately and consistently assess students' progress and provide appropriate supports (e.g., Worthen and Pace, 2014; Lampert, 2015; Pearson and Flory, 2015). Assessments also play a key role. In competency-based systems, assessments are given when students are ready to demonstrate they have learned the content and skills being assessed. Ideally such assessments require students to apply their knowledge and actually demonstrate their learning, rather than repeat memorized facts (JFF and CCSSO, undated; Brown and Mevs, 2012; Domaleski et al., 2015). In some systems, students may retake an assessment or revise their work until they have achieved mastery (Sturgis, 2012; Pearson and Flory, 2015).

Strategy 3: Learning happens anytime, anywhere.

A key aspect of SCL is engaging students in meaningful learning opportunities both within and outside the classroom so that students learn anytime and anywhere. In other words, this strategy suggests that learning should follow students' needs and interests, which would likely include activities, tasks, and courses that take place outside of traditional school hours and the school building. Implementation of this strategy could take a variety of forms—such as granting students access to course content and materials online, field trips or experiential learning, dual enrollment, or internships, jobs, or volunteer work. These experiences could be initiated by students (e.g., National Service Learning Cooperative, 1998) or organized by educators. These opportunities should allow students to earn credit or opt to demonstrate mastery based on learning that takes place outside of school, so that learning will “count” toward high school graduation (Donohue, 2010). Indeed, The National Youth Leadership Council’s standards for high-quality service learning (Billig, 2008) suggest that it should be linked to the curriculum and be formally recognized as a learning activity.

Strategy 4: Learning opportunities promote student agency and ownership.

It stands to reason that students must be able to exercise agency and ownership over their learning in order for learning to be “student-centered.” As with the other SCL strategies, what student agency and ownership look like can vary, but in general, this strategy suggests that students are taught, and employ, approaches to self-regulation (e.g., good study habits, the ability to persevere on challenging tasks), collaboration, metacognition, and communication. In addition, students must demonstrate control over their learning pathways—that is, they should be able to make well-informed choices about their learning and provide meaningful input regarding what, how, when, and where they learn—and also engage in challenging tasks and activities with appropriate supports (Cervone and Cushman, 2012; Shubilla and Sturgis, 2012; Bertrand, Allen, and Steinberg, 2013; Mehta and Fine, 2015).

In some ways, students who exercise agency and ownership over their own learning are demonstrating engagement, which is an assumed outcome of all the strategies we have outlined thus far. At the same time, the strategies we have already discussed could all be expected to encourage students to exercise agency and ownership over their learning. Thus, one focus of this strategy is the explicit support that educators provide to encourage students to exercise agency and ownership over their learning. Specifically, this encompasses the ways in which educators teach students approaches to self-regulation, collaboration, and communication that can support more learning. Researchers sometimes refer to this work as teaching students “metacognitive strategies,” or learning about learning (Bitter et al., 2014). The other focus of this strategy is to consider the extent to which students are demonstrating agency and ownership, in terms of self-regulation and other strategies that show they are monitoring and making well-informed choices about their own learning.

Strategy 5: Learning is informed by data.

Learning that is student-centered necessarily relies heavily on “student data,” which we define as any information about students’ goals, learning needs, and progress toward learning targets (Hamilton et al., 2009; Coburn and Turner, 2012; Datnow and Hubbard, 2015). It would be difficult to personalize learning in competency-based systems without both (a) gathering various kinds of data on students’ needs, interests, and progress and (b) using that data together to design personalized learning pathways; develop challenging, competency-based courses, lessons, and assignments inside and outside of school; and help students set and monitor goals.

Ideally, the data that are collected would include regularly updated information about students’ academic and non-academic learning goals, needs, and interests; what content and skills they have mastered; where they need extra help; and what they have yet to learn. In particular, educators would work with students to track students’ goals for their future, such as the topics that they hope to study in more depth and whether they anticipate attending college or entering a career after graduation.

A range of assessments should also be used to track student progress, including teacher-generated assessments, schoolwide common assessments, and externally developed standardized tests as well as in informal assessment procedures such as students’ responses to questions or their contributions to class discussions (Ruiz-Primo, 2011; Hoover and Abrams, 2013; Datnow and Hubbard, 2015). To support effective data use, such assessments must be regularly administered, aligned with students’ learning needs and key competencies, and the results regularly incorporated into the set of data that informs students’ learning plans (Friedlaender et al., 2014; Conley, 2015).

Through collection and use of these data, educators and students can develop a clear and evolving understanding of each student’s need for support (e.g., provide supplementary materials, choose particular learning strategies (JFF and CCSSO, undated; Lampert, 2015)). Learning plans or learner profiles, which were mentioned as part of Strategy 1, are shaped by student data but can also support data-driven discussions by giving educators and students the ability to track student progress toward goals and point to adjustments in the instructional support necessary to help students meet their goals.

The frequency of conversations about data might vary depending on students’ needs, but some evidence suggests that such conversations should occur more frequently than regular marking periods (Hamilton et al., 2009). Beyond involving educators and students in the use of data, schools must ensure that educators and students, along with parents/guardians, have access to this information and work together to use it to inform learning pathways and monitor progress. In all, the use of data is necessary if the other SCL strategies are to be implemented to the fullest extent.

Associations Between SCL Strategies and Student Outcomes in the Literature

While the strategies and practices we have discussed are considered by many experts to be integral to SCL, the research base for showing that these strategies are associated with desired student outcomes—including the short- and long-term outcomes listed in our conceptual framework in Figure 3.1—is relatively thin. It is possible, however, that more-extensive SCL implementation is related to improved student outcomes. Instead, we found that most of the rigorous SCL research—that is, quasi-experimental studies—often evaluated large-scale SCL interventions (i.e., those taking place in multiple sites focused on implementation of multiple SCL strategies) and did not assess the efficacy of particular practices that were part of those interventions. Below we describe these large-scale studies of SCL interventions. Following this, we summarize the research related to each of the key SCL strategies we highlighted in our conceptual framework: personalization of instruction; competency- and mastery-based learning frameworks; anytime, anywhere learning approaches; and explicit support for student agency and ownership over their own learning.

Outcomes Associated with Large-Scale SCL Interventions

There is some evidence that implementation of a variety of student-centered interventions can improve student engagement and performance under some conditions (Friedlaender et al., 2014; Steele et al., 2014; LaBanca et al., 2015; Pane et al., 2015; Pane et al., 2017b). These studies all used a quasi-experimental design and matched comparison groups. However, the interventions examined in these studies included a variety of SCL approaches—e.g., use of real-world problems, use of particular software, building positive relationships with students, providing students with choices in content or mode of instruction, flexible scheduling, learner profiles, competency-based approaches—and thus do not provide guidance on the specific practices that most contribute to learning. Taken together, these studies suggest that SCL approaches can have mixed effects on student achievement and engagement. Our review did not include any studies that explicitly examined the effects of SCL on closing opportunity and achievement gaps or on career/college readiness.

Steele and colleagues (2014) examined schools in three districts that implemented a variety of SCL practices, with variable pacing and student choice in content or instructional method being consistent across all the sites. While student perceptions and self-reports of engagement were positive, achievement results varied. The authors found that achievement effects were more positive—and teacher concerns about equity less frequent—in sites that emphasized student choice, rather than variable pacing. The authors also identified a trend toward disengagement and apathy among lower achieving students.

Another study of 12 urban schools (LaBanca et al., 2015) that implemented SCL approaches including technology-based curricula, experiential learning, and digital portfolios found increases in student achievement, particularly in science, and particularly for female and low-

income and minority students. Student self-reports of engagement did not change over the course of the study, but students did report positive perceptions of the school model.

Similarly, a study of four schools that served large proportions of low-income and minority students found that students at schools that incorporated SCL approaches such as explicitly building relationships with students, crafting engaging assignments and assessments, and providing data-driven supports were more likely to feel a sense of purpose and connection to school, outperform similar students on state tests, graduate high school, and attend and persist in college (Friedlaender et al., 2014).

A more recent study of 62 schools implementing personalized learning approaches (e.g., student choice in path and content, competency-based approaches, flexible learning pathways) found large positive effects on student achievement in reading and math achievement over two years (Pane et al., 2015), although a subsequent report that included a subset of 40 schools found smaller positive effects (Pane et al., 2017a; Pane et al., 2017b).

In addition, the concept of “deeper learning” is closely linked to SCL in that it promotes mastery of core academic content and skills, critical thinking, communication, collaboration, and learning how to learn (that is, learning strategies such as effective study habits and self-regulation) (Bitter et al., 2014; Huberman et al., 2014; Zeiser et al., 2014; Heller and Wolfe, 2015; Huberman et al., 2016). According to these studies of schools that espouse deeper learning, some strategies used within those schools were consistent with SCL approaches (e.g., internships and other opportunities to connect students to the real world and group work and long- term assignments). Recent studies of deeper learning have found that students in deeper learning schools scored higher on the Organisation for Economic Co-operation and Development’s Programme for International Student Assessment for schools in reading, mathematics, and science, as well as on state ELA tests, than similar students in comparison schools (Bitter et al., 2014). Students in deeper learning schools were also more likely to graduate on time and enroll in college (Zeiser et al., 2014).

Outcomes Associated with Personalization of Instruction

Although there is extensive literature examining various strategies for personalizing content based on student interests, there is less clear evidence from rigorous empirical studies to suggest that this approach results in improved achievement. That said, some suggestive evidence indicates that personalization can lead to improvements in students’ attitudes toward learning. In several studies, teachers personalized mathematics word problems according to student interests, using information provided by students on a brief classroom survey. Such personalization was not linked to change in student performance on the word problems or motivation to solve them for fourth-grade (Bates and Wiest, 2004) or seventh-grade students (Cakir and Simsek, 2010); however, increases in achievement were seen for

middle and high school students, whose attitudes toward learning mathematics also improved (Ku and Sullivan, 2002; Awofala, 2016).

Another study of seventh-grade students reported more positive attitudes after participating in two days of mathematics instruction in which the word problems were personalized using information provided by students, even though there was no clear evidence that performance improved (López and Sullivan, 1992).

An experimental study using adaptive technology to personalize algebra story problems based on student interest also observed a relationship between personalization and students' learning, in terms of their ability to write symbolic equations with more complex structures and greater efficiency (Walkington, 2013).

Although there are numerous technology-based programs that offer ways for teachers to create playlists—lists of tasks and assessments that can be customized to the needs, interests, and preferences of each student—few such programs have been the subject of rigorous evaluation and those that have returned mixed results (Cole, Kemple, and Segeritz, 2012; Ready, 2014). Programs that adjust content and assessment questions based on students' prior performance have been found to improve student achievement in some studies when compared to teacher-provided instruction (Pane et al., 2013; Gerard et al., 2015; Brodersen and Melluso, 2017), although one recent review reported mixed effects (VanLehn, 2011).

We did not locate research on whether specific aspects of personalization were more fruitful for supporting better student outcomes than others. For example, while much of the research we cite above suggests that personalization of content may support improved student outcomes, that research did not compare personalization of content to personalization of instructional delivery or assessments. Thus, we do not know whether it is preferable to personalize particular aspects of instruction over others.

Outcomes Associated with Competency-Based and Mastery-Based Learning Frameworks

Two core competency-based learning approaches—working at one's own pace and multiple opportunities to retake assessments until competency is reached—have long been in use at the postsecondary level. A sizeable body of older literature, including several meta-analyses, (Kulik, Kulik, and Cohen, 1979; Guskey and Pigott, 1988; Kulik, Kulik, and Bangert-Drowns, 1990) suggests that the effects of these mastery-based approaches on student learning and affect (i.e., motivation and engagement) are consistently positive, although effect sizes vary. However, these meta-analyses include only a few studies of mastery-based approaches in K-12 schools. Although the definition of competency (or mastery) in these older studies is somewhat different from today's definition (in these older systems, teachers set the pace but students retook assessments until they passed), this approach had positive effects on

test performance for students in high school and upper elementary grades (Kulik, Kulik, and Bangert-Drowns, 1990). In general, positive effects of mastery-based systems were stronger for lower-performing students. The mastery-based approaches used in these studies also had positive effects on student attitudes toward course content and instruction but were found to increase the amount of time students spent learning the material (Kulik, Kulik, and Bangert-Drowns, 1990).

More recently, an instructional method called the Mastery Learning Approach or MLA has been in use in Kenya (Wachanga and Gamba, 2004; Wambugu and Changeiywo, 2008; Abakpa and Iji, 2011). The MLA requires teachers to develop clear tasks and objectives, and break down the subject matter into units of learning, each with its own objectives. Students have unlimited opportunities to demonstrate mastery of content taught, and mastery is achieved when students pass the unit diagnostic test. In several quasi-experimental studies of Kenyan high school students, this approach was used in physics, chemistry, and geometry classrooms for two to three weeks, and students' performance was compared to that of students in the same school who did not experience the MLA. The treatment and control groups performed similarly on the course assessments prior to implementation of the MLA. All three studies found that students in the MLA classrooms performed significantly better on the unit diagnostic tests.

Several studies of a range of other competency-based systems have found positive effects. For example, a recent study of four non-selective California schools participating in the Linked Learning or Envision Education models found that students in schools that used rigorous competency-based assessments and tasks, along with strong academic supports, outperformed similar students in other schools in the same district and were more likely to graduate on time and attend college (Friedlaender et al., 2014). In another, different competency-based system that required students to master specific learning targets before progressing, students reported greater intrinsic motivation (i.e., self-motivation to learn), some improvements in self-efficacy, and greater clarity of understanding of learning targets (Haynes et al., 2016). However, another study of competency-based approaches in three districts found mixed results, and a trend toward disengagement and apathy among lower achieving students (Steele et al., 2014). Lastly, the studies of deeper learning, which focuses on mastery of core academic content (described above: Bitter et al., 2014; Huberman et al., 2014; Zeiser et al., 2014; Heller and Wolfe, 2015; NMEF, 2015; Huberman et al., 2016) found that students' self-reports of engagement in learning were higher in deeper learning schools than in comparison schools.

Thus, there is some evidence to suggest that providing students with numerous opportunities to demonstrate mastery of the content taught may improve student achievement although it can increase the amount of time it takes students to learn the content. None of these studies utilized a randomized controlled trial approach that would allow for strong, causal

conclusions regarding the effects of competency-based systems. Moreover, each of these competency-based approaches varied somewhat in terms of features and supports for students. Nonetheless, taken together, these studies provide some suggestive evidence that competency-based systems can improve students' attitudes, motivation to learn, and their performance.

Outcomes Associated with Anytime, Anywhere Learning Approaches

Two particular approaches to anytime, anywhere learning that have been the subject of much research are use of online or blended approaches and use of "service learning" approaches. Research is decidedly mixed on whether online or blended approaches improve student engagement or learning. In contrast, the case for service learning approaches is somewhat more compelling and suggests that such opportunities can support student engagement and learning.

Most empirical research related to anytime, anywhere learning approaches focuses on outcomes related to use of online and digital curricula. Use of such programs is increasingly common, and one advantage is they can be made often accessible to students outside the classroom. Recent studies of online or distance learning suggest little difference in effects of those programs delivered online versus traditional settings. For example, a meta-analysis (Cavanaugh et al., 2004) found no significant differences in achievement between students who received instruction delivered online and students who received instruction delivered in traditional classrooms. Similarly, a comprehensive literature review (Rice, 2006) emphasized that differences in the effectiveness of distance learning programs are more likely attributable to instructor experience and quality, or differences among students, than to the mode of delivery (Bernard et al., 2004; Sener, 2005).

More recent research examines the efficacy of instructional approaches that combined online and digital materials with face-to-face instruction in brick-and-mortar classrooms, often called "blended learning." A recent meta-analysis of multiple studies on blended learning suggested that some, but not all, blended learning approaches are associated with more powerful student outcomes (Means et al., 2010). One additional review of research also suggested mixed effects in some studies of blended learning when compared with traditional instruction (Yonezawa, McClure, and Jones, 2012).

School-based service programs can provide opportunities for students to engage with their communities and, at the same time, serve an educational purpose by explicitly linking community service experiences to classroom instruction. In a quasi-experimental study, Furco (1996) examined the effects of three predominant forms of service programs (community service, service-learning, and service-based internships) among high school students, and found that service programs, regardless of type, led to positive student

attitudes toward school, themselves, others, the future, and their community. Later meta-analyses supported these findings and also associated service programs to positive gains in academic performance and stronger civic engagement (Billig, 2000; White, 2001; Conway, Amel, and Gerwien, 2009; Celio, Durlack, and Dymnicki, 2011). While many of these studies provide evidence of positive impact toward student outcomes, the impact is generally small, and some studies are inconclusive (Eyler, 2002). Eyler and Giles (1999) suggested that the modest effects may be attributable to the great variability in implementation of programs, and programs that connect service experience with curriculum through extensive reflection are associated with stronger student outcomes. As a result of an extensive review of the literature on service programs, the K-12 Service-Learning Standards and Indicators for Quality Practice was published in 2008, which listed the eight essential elements and best practices of service-learning (Billig, 2008). In a quasi-experimental study, Billig (2009) reported that high-quality programs, as defined by these standards, showed positive outcomes on academic achievement, attendance, tardiness, and suspensions.

Beyond research on blended or online approaches and service-learning, we know little about the broad approaches to anytime, anywhere learning that might lead to improvements in students' engagement and learning. That said, we limited our review to the most common approaches for supporting student learning outside of school walls that are consistent with SCL. Therefore, there may be some specific approaches taken by individual schools or districts (e.g., particular internship programs) that have been evaluated but were not reviewed here.

Outcomes Associated with Data Use

An extensive body of research examines the ways that educators use data for decisionmaking and the factors that influence that use. For example, in a review of several studies that address data-driven instructional practices in schools, Marsh, Pane, and Hamilton (2006) noted that data use is a key input into educators' decisionmaking process. They observed that educators perceive formative, frequent assessment that is tied to the curriculum, and analysis of student work, to be more useful than state tests. Educators also reported using multiple sources of student data to develop school improvement plans and target instructional strategies. Some descriptive reports of teacher data use noted that when teachers use multiple sources of student data to reflect on their instructional strategies they believe it improved their subsequent instruction (DiPietro et al., 2008).

While research suggests that student data can support better school decisionmaking, little evidence exists regarding the effects of data use on academic achievement or other student outcomes (Jimerson, Cho, and Wayman, 2016). Of the five broad practices recommended in the 2009 What Works Clearinghouse Practice Guide (Hamilton et al., 2009), the one that was supported by the most evidence (albeit fairly weak evidence) was the recommendation to

engage students in the analysis of their own data. Students are sometimes viewed as mere recipients of data, but research suggests that engaging students actively in making sense of data and in contributing to decisions about next steps has been associated with improved student learning. For instance, in a randomized controlled trial, May and Robinson (2007) explored students' engagement with a website that reported test performance and offered suggestions for improvement. The study found a positive relationship between student achievement and use of the website. Conditions that might support effective engagement of students in data use can include the development of a classroom culture, norms, and routines that encourage students to share and make sense of this information (Hamilton, 2011), along with interpretive guidance and thoughtful feedback from adults to help students develop strategies to build on their strengths and address weaknesses (Black and Wiliam, 1998).

Outcomes Associated with Metacognitive Instruction Intended to Support Student Agency and Ownership

As discussed earlier, there is evidence that students' mastery of self-regulatory strategies is associated with their engagement and performance in school (Pintrich and De Groot, 1990; Wang and Holcombe, 2010; Nagaoka et al., 2015). There is also a fairly large body of evidence that teaching students self-regulatory and metacognitive strategies can lead to improvements in students' performance, as well as their knowledge about their own performance.

Metacognitive strategies may vary somewhat, depending on the subject area in which they are being taught. But such strategies generally include those related to planning—or knowing about oneself, what strategies to use in particular situations, and when to use them—and monitoring—checking or evaluating one's knowledge and understanding (Flavell, 1979; Schraw, Crippen, and Hartley, 2006; Lai, 2011).

In studies across multiple grade levels—including several employing experimental and quasi-experimental methods—teaching of strategies to engage in metacognition has been tied to increases in student performance and achievement (Cross and Paris, 1988; Cardelle-Elawar, 1992; Kramarski and Mevarech, 2003; Boulware-Gooden et al., 2007). For example, Cardelle-Elawar (1992) examined changes in mathematics achievement among lower achieving sixth-graders who were randomly assigned to receive a metacognitive instruction intervention. Features of the intervention included teachers' work to support students' thinking about their own mental processes, redirection of students during problem-solving, and encouraging students to use errors as a source of information and feedback. The study found that this approach enabled low-ability students to progress as problem-solvers and gain greater awareness of how to solve math problems and verify their solutions. In another experimental study, Kramarski and Mevarech (2003) found that eighth-graders receiving metacognitive training to ask themselves questions during problem-solving work significantly outperformed their peers on mathematics learning transfer tasks. Other experimental and non-experimental studies have found that students engaged with reading curricula designed

to increase their awareness of reading strategies made significant gains in their reading skills (Cross and Paris, 1988; Boulware-Gooden et al., 2007; Chamberlain et al., 2007). Meta-analyses of metacognitive research also consistently observe large and positive effects of metacognitive interventions on students' performance (Haller, 1988; Dignath and Büttner, 2008).

Research also points to instructional strategies that may be most productive in teaching students metacognitive strategies. Such strategies include explicit and direct metacognitive instruction, as well as highlighting the value of particular metacognitive strategies for students (Schraw, 1998; Kramarski and Mevarech, 2003; Cross and Paris, 2008). In addition, researchers also encourage use of collaborative or cooperative learning structures for metacognitive instruction (Schraw and Moshman, 1995; Kuhn and Dean, 2004; Cross and Paris, 2008), with the rationale that such structures can enable students to construct and internalize metacognitive strategies that support their own learning.

Contextual Conditions to Support Implementation of SCL Strategies

SCL represents a major shift from more traditional modes of schooling that have been in place for a very long time in some school systems. Implementation of SCL approaches across a school system requires the same supports necessary for the implementation of any ambitious reform that aims to make changes to the "instructional core," or teaching and learning within classrooms (Elmore, 1996). In this section, we summarize the contextual supports that are important for school systems to consider in implementing SCL reforms and—particularly—the five SCL strategies included in our conceptual framework (as noted in Figure 3.1).

Any ambitious reforms—including SCL reforms—are nested in a district and school context and thus dependent on that context to ensure their success (Coburn, 2005; Stein and Spillane, 2005; Cobb and Smith, 2008). Elements of the district and school context that researchers have highlighted as key to large-scale innovative instructional reforms include:

- Committed, transformational, expert leadership that supports reform efforts (Leithwood and Jantzi, 1990; Leithwood and Jantzi, 2000; Geijsel et al., 2003);
- Work among leaders and educators to develop and communicate a comprehensive and shared vision of school reform that aligns with other school priorities and foci (Bodilly, 1996; Datnow, 2000; Datnow and Stringfield, 2000; Banilower et al., 2006);
- Active partnerships with an array of stakeholders (Banilower et al., 2006);
- A comprehensive, long-term plan of adult learning events and professional learning communities focused on reform efforts across the school system (Desimone et al., 2002; Coburn and Stein, 2006; Hubbard, Mehan, and Stein, 2006; Coburn and Russell, 2008; Cobb and Jackson, 2012);

- Alignment among policies, tools (i.e., instructional materials supporting reform practice), and professional development supporting instruction (Coburn and Stein, 2006; Coburn and Russell, 2008; Kaufman, Thompson, and Opfer, 2016); and
- A commitment to system-wide quality assurance and continuous improvement through use of data to determine needs, progress, and improvement (Penuel et al., 2011; Bryk, 2015).

Adult learning is a particularly key component of SCL programs. Most educators were themselves taught in a traditional system and must learn how to transform how they think about instruction and student learning in order to implement SCL strategies effectively (Mehta and Fine, 2015; Scheopner Torres, Brett, and Cox, 2015). Much research suggests that one-shot teacher professional development trainings or traditional “sit and get” workshops are not enough to support adults to transform and improve their teaching (Little, 1993; Desimone et al., 2002; Borko, 2004). Instead, the aforementioned research emphasizes that educators need to be engaged in trainings that occur over a longer time period and involve extensive opportunities to make sense of reforms in interaction with other expert educators. Some research particularly suggests that professional learning experiences should focus on discussions about use of “tools” and instructional materials aligned with reform efforts (Borko, 2004; Coburn and Stein, 2006; Cobb and Jackson, 2012), as well as conversations about student work and how to improve it (Lesh and Lehrer, 2003). Other supports that researchers have regarded as useful or important for successful SCL reform include technological infrastructures and platforms that support online and digital learning (Glowa, 2013; Dede, 2014; Steele et al., 2014) and strong partnerships with external education providers and the community (Mehta and Fine, 2015).

Research also suggests that certain classroom conditions support implementation of more student-centered reforms. Logically, some of the system-level supports mentioned above could also be useful supports within classrooms themselves, including strong partnerships between teachers and external organizations and alignment between materials used in classrooms and SCL. A large body of research focuses on the qualities of classroom learning environments that can encourage student engagement. For example, studies have tied students’ engagement in learning to students’ perceptions that their teacher is respectful, caring, and supportive (Ryan, Stiller, and Lynch, 1994; Wentzel, 1997; Ryan and Patrick, 2001; Hughes et al., 2008; Reyes et al., 2012; Yonezawa, McClure, and Jones, 2012; Shernoff, Tonks, and Anderson, 2014). Some research suggests that supportive learning environments may be most effective at fostering student engagement when students are also presented with challenging, meaningful work (Ryan and Patrick, 2001; Shernoff, Tonks, and Anderson, 2014).

Literature Review Summary

In this section we reviewed the research literature related to the five key SCL strategies and contextual conditions outlined in our conceptual framework. Our review suggests that the evidence of the effect of large-scale, broad SCL programs on student engagement and achievement is mixed. However, some specific SCL strategies and associated practices have a stronger empirical basis. Specific aspects of SCL strategies with the clearest support in the research literature examining links between instructional practices and student outcomes include personalization of content based on students' interests; competency- or mastery-based systems—particularly those that allow students unlimited time to demonstrate mastery; service learning programs that are strongly linked to the curriculum; and teaching metacognitive strategies that give students an opportunity to plan and monitor their own learning.

Other practices related to SCL with less clear or consistent findings regarding student outcomes include those related to online or blended learning and data use. Regardless of whether the findings suggest a relationship between these practices and student outcomes, most of the research we reviewed emphasized that implementation of any SCL practice can look quite different depending on the SCL strategies and context for implementation.

Specific contextual conditions that the literature suggests might be important for successful implementation of SCL include committed leadership; a comprehensive, shared vision for reform; active partnerships with other stakeholders; a comprehensive, long-term adult learning plan; alignment among policy, tools, and professional development within the school system; a commitment to quality assurance and continuous improvement; and high-quality technological infrastructure and platforms to support online and digital learning. Research also suggests that contextual classroom learning conditions most likely to support SCL are those in which students perceive teachers to be respectful, caring, and supportive.

SECTION 4

MEASURING STUDENT-CENTERED LEARNING

We now turn our focus to literature and tools offering support on how to measure SCL. Our conceptual framework suggests that measures of SCL implementation should examine both educator and student practices and include measures addressing implementation at the classroom and system (i.e., school, district, charter management organization) levels. Measurement of educator and student practices in classrooms is crucial to understanding the extent to which SCL practices (e.g., students work at their own pace) are being equitably implemented, as well as to the role that teacher and student relationships—and other aspects of the classroom environment—play in SCL implementation. System measures, in comparison, might address district and/or school technological infrastructure, as well as policies and processes that enable and support personalization, competency-based frameworks, and other aspects of SCL. In addition, a comprehensive assessment of SCL implementation—based on our framework—would encompass both SCL strategies and the contextual conditions that might be expected to best support those strategies. Contextual conditions might include committed school leaders, a shared comprehensive vision for reform, and a long-term adult learning plan, among other factors.

To measure all these varied aspects of SCL implementation, we aimed to develop a variety of instruments to collect information from a variety of respondents at different “grain sizes,” or units of measurement. For example, we might survey teachers about their lesson for the day. In this example, the instrument is the survey, teachers are the respondent group, and the lesson is the unit of measurement. In another example, we might review artifacts with district administrators that discuss the sequence in which courses are offered throughout the district. Here, the rubric used to evaluate the artifact is the instrument, district administrators are the respondent group, and course sequencing at the system level is the unit of measurement. Feedback from our advisory board suggested that it is important to collect information at varying grain sizes to fully understand SCL implementation system-wide. In the next section, we discuss a variety of instruments that can be used to measure SCL at a number of grain sizes.

Definitions of Instrument Types

Our review of existing instruments revealed a variety of instruments that have been used across a number of different stakeholder groups to measure SCL in classrooms and systems at a variety of grain sizes. These are listed in Table 4.1 and briefly defined below, along with recognition of their benefits and drawbacks. A complete list of the instruments we reviewed is included in the appendix.

Focus Groups or Interviews

Focus groups are small group discussions (usually four to eight participants, although they can be larger) in which a facilitator asks questions. Interviews are individual conversations. Both approaches can be employed with a variety of stakeholder groups and can provide rich, detailed information at a variety of grain sizes. Participants can provide retrospective information about their own experiences and behaviors and report what they know about the behavior of others. However, they can be time-consuming to organize and conduct, and systematic analysis of data obtained in interviews or focus groups requires special training and can be burdensome.

Surveys

Surveys ask participants to respond to a set of specific questions, often using structured response choices, and can be administered to a variety of stakeholders. Participants can provide retrospective information about their own experiences and behaviors at a variety of grain sizes. Surveys are efficient ways of collecting a variety of information from large numbers of respondents, can be efficiently administered and analyzed online, and can be compared across classrooms or schools. However, surveys may not capture the full range of variation in instructional practices or experiences they measure as well as direct classroom observations might (see, for example, Kaufman, Stein and Junker, 2016). Research by West and colleagues (2016) suggests that a phenomenon known as “reference bias” can make self-reported data difficult to compare across respondents, given that different people can interpret response choices like “a little” or “a lot” in different ways.

Survey Vignettes: Vignettes are short hypothetical descriptions of specific activities or behaviors (e.g., teachers’ instructional practice) and are used to anchor—or provide a common reference point—for participants’ perceptions of those practices. Establishing a common reference point helps improve comparability across groups. Vignettes are often used in teacher surveys. In the context of SCL, they could be used to improve understanding of variation across groups when comparing survey results across classrooms or schools. However, vignettes can be time-consuming to develop and somewhat complicated to analyze.

Daily Logs: Daily logs are short surveys—typically taking five to ten minutes to complete—that ask for information about teachers’ or students’ daily activities and experiences. For example, daily logs for teachers might ask about the source of lesson materials, the extent to which certain instructional strategies were used, and what supports were provided to students. Daily teacher logs are generally completed with reference to a particular “target student,” which provides a reference point the teacher can use to answer questions about instructional strategies and supports. Daily logs are typically administered for ten days (two weeks) in a row, at least twice per year. Daily logs can be burdensome to administer, and are more complicated to analyze than a survey taken at one point in time.

Observations

Observations are real-time, in-person opportunities to collect evidence about events such as teachers' instructional practices, students' behavior, or the content of professional development sessions. Observation instruments generally include a list of items (e.g., specific instructional practices) to look for, and a rubric on which to rate the quality of implementation (where relevant). Observation tools and rubrics generally require training before they can be used with confidence—it is important to ensure that observers are consistently interpreting and scoring what they see and that consistency is achieved across multiple independent observers. Collecting observational data is time-intensive and requires special training, and the data analysis can be complicated.

Artifacts

Artifacts are extant items of information that can range from lesson plans and assessments to student work to district policy documents. Artifacts are typically gathered and then rated using a rubric, although some artifacts can be summarized. Ideally, artifacts would be rated by independent raters using the same rubric, and then the ratings compared to ensure consistency. Accurate artifact review requires training and practice, and gathering and analyzing data from artifacts can be time-consuming.

Walkthroughs

Walkthroughs are opportunities to collect real-time, in-person evidence about activities (like teachers' instructional practices) or resources (e.g. libraries, instructional materials), but they are generally shorter and less formal than observations. Walkthroughs typically direct observers with a list of things to look for, and the resulting findings are often rated with a rubric. Using multiple observers who will then discuss their ratings and agree upon a final, single score is preferable. Although training is required to use a rating rubric consistently, walkthroughs are less time-consuming than observations but the evidence collected may not be as detailed.

Event Sampling

Event sampling, also known as experience sampling or momentary sampling, is a way to collect real-time data on respondents' experiences and events as they occur. Typically, this is done by asking respondents to keep a diary, or, increasingly, respond multiple times per day to a quick survey, often via smartphone. Event sampling can provide good information on the variation in respondents' experiences throughout the day and over time. This method could capture, for example, variation in students' experiences of SCL approaches across classes within a day as well as over several days. Although the data would be rich and informative, event sampling approaches can be complex to administer and the data time-consuming to analyze.

Tool Review Analysis

We focused our tool review on instruments that were designed to measure practices associated with the five key SCL strategies. Our review captured a total of 99 instruments, which we coded for the following key characteristics; the full list of instruments and coded information is in the appendix.

- **Title:** instrument title
- **Focus Area:** which aspects of the learning environment the tool is designed to measure (e.g., district, school, classroom, or community); each tool can cover more than one focus area
- **SCL Constructs:** the SCL-related constructs (i.e., topics, main ideas) that the instrument measures
- **Instrument Type:** the type of instrument (e.g., survey, interview protocol)
- **Respondent Group:** the group that is intended to respond to, or complete, the instrument
- **Validity/Reliability Information:** whether information about validity or reliability of the instrument—that is, evidence on whether the instrument consistently measures what it was designed to measure—was available.

Half of the tools we reviewed were surveys (50); interview or focus group protocols were also relatively common (17) as were practice guides and templates (12) (e.g., assessment or lesson plan templates). We did not find many examples of rubrics, daily logs, observation tools, and walkthrough instruments. Table 4.1 presents the type of tool by respondent group. As shown in Table 4.1, the most common respondent group was students, followed by leaders, school staff, and instructional staff. We found a number of tools that were not specific to one target user—for example, we found 17 tools designed to be used by school staff; that is, instructional staff or school leaders. We did not find any examples of event sampling that focused on SCL. However, we did find 12 examples of practice guides, which provide guidance for educators on how to implement specific instructional strategies or practices and often include examples. Although practice guides are not instruments used to measure SCL, we include them here because they could offer valuable insights for instrument development. The examples of practice guides included in our review included lesson and assessment plans, as well as a series of workshops for educators focused on how to implement personalized learning practices.

Table 4.1 Instruments Reviewed by Respondent Group

Type of Instrument	Respondent Group								TOTAL
	Leaders	State or District Leaders	School Leaders	School Staff	Instructional Staff	Staff and Students	Students	Parents	
Interview and Focus Group Protocols	4	2	2		2	1	5	1	17
Survey	4	4	2	7	13	1	21		52
Survey Vignettes							1		1
Daily Log					1				1
Observation			5		1				6
Rubric	2		1	7					10
Practice Guide	7			2	1		2		12
Walkthrough				1			1		2
TOTAL	17	6	10	17	18	2	30	1	101

Note: School Staff refers to both school leaders and instructional staff; Leaders refers to state, district or school leaders.

Our tool review also took note of the focus area, or the aspects of the learning environment the instrument was designed to measure. Most instruments measured more than one focus area—for example, many surveys included questions about classroom-level and school-level strategies and conditions. The most common focus area across the instruments we examined was the classroom, (e.g., classroom and instructional practices, teacher-student relationships, classroom climate; 96 instruments), followed by student constructs and experiences (e.g., student engagement, student agency, peer relationships; 73 instruments) and school policies, processes, and practices (68 instruments). Instruments that focused on district and community perspectives were less common (32 instruments each). The emphasis on the student, classroom, or school level is perhaps not surprising given the emphasis on school and classroom practices and student experiences evident in the SCL literature. We also reviewed the intended purpose of each instrument; that is, whether it was designed to be used for planning (e.g., planning SCL implementation), evaluation/research, or both. Slightly fewer than half of the tools we found (44) were designed to serve both purposes and about one-third of the total was designed to be used either for planning or for evaluation.

We listed the SCL constructs covered by each instrument, and then consolidated these into a few key constructs (e.g., teaching quality, school or classroom climate, technology use, mastery-based learning/instruction, teacher/student relationships). We then consolidated further, using these constructs to code the instruments for the key SCL strategy they addressed and whether the instrument addressed contextual conditions at the district, school, classroom, or community level. Most instruments addressed multiple constructs

and strategies, as well as contextual conditions; we coded for all applicable strategies and contextual conditions. The instruments captured in our review covered all five key strategies. We found the most tools related to competency-based learning (53) and the fewest related to data use (15). We found fewer tools that addressed contextual conditions at the district level (5), but numerous tools that were designed to capture school- and classroom-level contextual conditions (39 and 25, respectively). Table 4.2 shows these counts for each strategy and contextual conditions. We discuss the advantages and disadvantages of various types of tools in the next section.

Table 4.2 Instruments that Capture Each of the Five SCL Strategies and Contextual Conditions

Strategy	Instrument Type								TOTAL
	Daily Log	Interview and Focus Group Protocols	Observation	Practice Guide	Rubric	Survey	Vignettes	Walkthrough	
1. Personalized Learning	1	4	2	4	3	15		1	30
2. Competency-Based Learning		10	4	7	7	27			55
3. Anytime, Anywhere Learning	1	6	3	2	1	18		1	32
4. Student Agency and Ownership		4	5	8	3	26		2	48
5. Data Use	5	1	1	1	6		1		15
Context: District		3			1	1			5
Context: School	7	1	3	2	27		1		41
Context: Classroom	1	4		3	1	16	1	1	27
Context: Community		4		1		10			15
TOTAL	3	47	16	29	19	146	1	7	268

Key Themes from the Tool Analysis

Next, we discuss what our analysis of existing tools implies for the development of a comprehensive, user-friendly tool to measure SCL implementation. We discuss the coverage of relevant topics; the different types of information that can be gathered by certain tools, and the level of effort required to administer them; and conclude with a discussion of additional challenges related to measuring SCL.

Different instruments provide different types of information and require different levels of effort. Users of the Measuring Student-Centered Learning Toolkit could include educators at the classroom and system levels, and researchers, all of whom will have different levels of measurement expertise and varied amounts of time to train data collectors, administer these instruments, and analyze the data. Our aim was to develop a suite of instruments that users with different levels of expertise, time, and other resources can use as a comprehensive tool, or can pick and choose among them. As such, the tool we developed includes measures that are valid, gather evidence from several different respondent groups, and are not overly burdensome to administer. Therefore, as we reviewed possible instruments, we took note of three key features:

- How burdensome the instrument might be to administer and analyze.
- The type of information each instrument would collect—real-time or retrospective. Real-time information is collected as the event is occurring, and retrospective information consists of respondents' memories about their behavior, opinions, or experiences. Real-time information is often more accurate than retrospective information, but can be more time-consuming to capture and analyze.
- Whether the information is reported by the respondent about their own behavior (i.e., self-report) or reported by others (i.e., other-report). Each can provide a different perspective and both are important for measuring the extent of SCL implementation.

A summary of potential instruments we considered is presented in Table 4.3. As we discussed above, it is important for the tool to include instruments that capture information at a variety of grain sizes (e.g., lesson, course sequencing at the system level). Each of the instruments included in Table 4.3 could capture information about SCL implementation at a variety of grain sizes.

To assess burden, or the effort required to use a particular instrument, we considered two dimensions—ease of administration and ease of analysis—and rated each measure as “low,” “medium,” or “high” on those dimensions. To rate burden of administration, we considered the time and other resources required to administer the instrument. Measures that required more time to create and deploy, as well as a larger time commitment from the participant, such as daily logs, were considered more burdensome to administer. To rate burden of analysis, we considered the time and effort required to train those who might analyze the instrument in a way that would ensure validity, as well as training needed to make use of the data once analyzed. Table 4.3 shows these overall ratings. Next, we discuss the findings from our review of tools that could be used to measure SCL implementation, as well as challenges and limitations.

Table 4.3 Potential Instruments for Measuring SCL

Instruments	Burden	Respondent Group					
		District Administrator	School Administrator	Teacher	Student	Parent	Community Member
Focus group/interview protocol	AD = Low AN = Medium	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective
Survey	AD = Medium AN = Medium	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective	Self-report Retrospective
Survey vignette	AD = Medium AN = High	N/A	N/A	Self-report Retrospective	Self-report Retrospective	N/A	N/A
Daily logs	AD = Medium AN = High	N/A	N/A	Self-report Retrospective	Self-report Retrospective	N/A	N/A
Observation	AD = Medium AN = High	N/A	N/A	Other-report Real-time	Other-report Real-time	N/A	N/A
Artifacts	AD = Medium AN = High	Other-report Retrospective	Other-report Retrospective	Other-report Retrospective	Other-report Retrospective	N/A	N/A
Walkthrough	AD = Low AN = Medium	Other-report Real-time	Other-report Real-time	Other-report Real-time	Other-report Real-time	N/A	N/A

Note: Burden: AD: administration, AN: analysis

This work to examine burden of various types of tools highlights a consistent tradeoff for development of any instruments: balancing efficiency and burden with the potential quality of the information that we might collect. Kennedy (1999) accurately summarized this concern; she specifically noted that researchers continually strive to gather evidence that students are engaged in “complex learning” or ambitious and rigorous intellectual student work, which is also typically the kind of student work embraced by proponents of SCL. Since standardized tests may not capture the extent of complex learning, researchers may rely on what Kennedy has called “approximations” of that learning. For Kennedy, direct observations are a kind of “first-level approximation” of complex learning. In contrast, second-level approximations are daily survey logs or vignettes, which enable teachers to report upon specific practices that are “situated” in particular situations or settings. Third- and fourth-level approximations are surveys or interviews designed to capture generalities in teachers’ practice. As we note below, surveys and interviews have the advantage of being efficient and easy to administer but may not yield the quality of information that more time-consuming observations or logs do.

Surveys are an efficient way to gather information, but responses can be difficult to interpret. As can be seen above, the majority of the instruments we found were surveys of students, school staff, and state or district administrators. In general, the surveys focused on teacher reports of their classroom practices and student reports of their classroom experiences (e.g., The University of Chicago Consortium on School Research, 2015; AIR, 2016b; Education Development Center, 2016; Ryan and Cox, 2016). Several also included questions about system-level factors, such as administrator support, professional development, or source of curriculum materials (e.g., National Center for Education Statistics, undated; Murphy et al., 2014; RAND Corporation, 2015). Surveys have the advantage

of being relatively low-burden to administer and analyze, particularly if they are online, and can be an efficient way of collecting a wide variety of information from many individuals at a variety of grain sizes. In addition, validity information is available for many of the surveys in our review, which could be useful as we vet the instruments for inclusion in our tool.

However, surveys collect retrospective, self-reported information, or what Kennedy (1999) would refer to as third- or fourth-level approximations. The retrospective nature of surveys raises concerns about accuracy of the reports—respondents may not accurately remember the practice or situation in question. The self-report nature of the surveys may also limit the ability to accurately measure differences across classrooms or schools. West and colleagues (2016) have documented a phenomenon known as reference bias, where responses can be influenced by the respondent's frame of reference or social context. For example, a student might answer a survey question about being “given opportunities to work at my own pace,” with the response option “mostly true.” The actual amount of such opportunities required to elicit a response of “mostly true” could vary from student to student, and could be influenced by their own experiences as well as the norms of the school or the attitudes of their peers. Thus, two students who responded “mostly true” might actually be experiencing different levels of these opportunities. This problem can reduce the validity of comparisons of responses between groups, such as schools. In another example, survey self-reports can provide inflated estimates of instruction, especially in regard to ambitious instructional practices (e.g., practices like problem-solving) for which researchers, teachers, and students may all define differently (Mayer, 1999; Spillane and Zeuli, 1999; Hill, 2005; Kaufman, Stein, and Junker, 2016). The usefulness of surveys can also be limited by sampling constraints, such as limited generalizability if the survey is not administered to a representative sample, if response rates are low, or if the responses are not weighted appropriately.

Student surveys, however, can be useful for capturing some of the variation in students' instructional opportunities or experiences. Although surveys are retrospective and are subject to the concerns related to self-reported information and reference bias described above, there is some evidence to suggest that student surveys, when combined with other measures, can increase the likelihood that the overall measure is reliable (Kane and Staiger, 2012). In addition, the inclusion of student perspectives may be especially useful for examining equity of SCL implementation. However, use of student surveys to better understand equity also raises concerns related to lower response rates for particular subgroups of students (e.g., those from low-income or high-risk groups).

Innovative instruments, such as observations and artifact rubrics, gather rich data but are time consuming to administer and analyze. Rubrics are often used as part of classroom observation tools or as a framework for analyzing artifacts such as lesson plans or examples of student work, or what Kennedy (1999) might refer to as first-level approximations because they provide direct evidence of what teachers and students are doing in the classroom. These

measures, such as the AdvancED classroom observation tool or the Depth of Knowledge Rubric (Webb et al., 2005; AdvancED, 2014) can provide a wealth of detailed data about instructional practices and student experiences. Such measures are commonly used by administrators (and, occasionally, teachers), provide rich data, and are particularly useful for measuring SCL because they have the potential to capture variation in students' experiences and opportunities. Classroom observation rubrics, in particular, are real-time measures that rely on information reported by others, and thus avoid some of the problems with surveys. However, consistent use of observation rubrics requires extensive and continuous training of observers (Bell et al., 2012) and such efforts may be prohibitive for many schools or districts. Information about validity and reliability was not available for most of the instruments that require rubrics we cataloged, suggesting that use of such a measure would require validation in different contexts before it could be widely used.

Our review noted several instruments, such as teacher and student daily logs, classroom observations, and artifacts, which have the potential to capture variation in SCL practices, particularly at the classroom level. However, as we applied our ratings of burden to each type of instrument, we found, not surprisingly, that several of these more innovative instruments are likely to be more burdensome for schools to administer and analyze. As we discussed above, valid use of observation and artifact rubrics requires extensive user training and can be time-consuming to analyze. Similarly, although teacher and student logs can be somewhat less burdensome to analyze, they also require large investments of time to administer and complete. Although these instruments can provide useful, real-time data—particularly on variation in student experiences with SCL—we aim to create a tool that can be used by practitioners as well as researchers and funders. As we develop the tool we will balance the competing demands of incorporating a variety of stakeholder groups, grain size, and burden to construct a suite of measures that users could opt to administer or choose among.

Instruments that include contextual conditions cover a wide variety of topics. Most of instruments that captured contextual conditions focused on school- and classroom-level implementation of and supports for SCL. Instruments that addressed district- and community-level contextual conditions were less common. When we looked across all the instruments that measured contextual conditions, we found that they captured most of the conditions and supports we discussed earlier in this report. Many teacher and student survey instruments included questions about system-level factors, such as administrator support, school or classroom environment, professional development, or source of curriculum materials (e.g., Priest et al., 2012; Future Ready Schools, 2015; New England Secondary School Consortium, 2016). However, few focused on policy supports, such as the extent to which instructional materials and assessments aligned with SCL, whether the system has clear and transparent systems for tracking student progress, quality of staff, or the extent to which the system has strong partnerships with outside organizations.

Developing an informative, user-friendly tool requires balancing measurement and logistical challenges. In addition to the measurement challenges we note above, a number of challenges are inherent specifically to measuring SCL at the classroom and system levels. First, because SCL promotes a personalized approach to teaching and learning, it is likely that student experiences with SCL practices will vary by student, day, or lesson. This variation is an important—and often an intentional—part of SCL but can be difficult to capture. Instruments that facilitate capturing detailed information about individual student experiences over time, such as classroom observations, teacher or student logs, or rubrics for analyzing student work can be burdensome to administer and difficult to interpret. Second, measuring the extent of SCL implementation at different grain sizes could look different depending on the grain size measured. SCL could be implemented in individual classrooms, for example, even in the absence of whole-school or whole-district policies or supports. A third challenge is that many existing classroom-level instruments designed to measure SCL focus more on process and less on the content of instruction and aspects of deeper learning that are likely important for supporting the improved outcomes of SCL (e.g., Kennedy, 1999). Fourth, most instruments we found do not capture learning that occurs outside the classroom and school day, or learning that occurs through online or software platforms, and our search revealed few instruments that are specific to high school settings. Fifth, a number of the instruments we cataloged are most efficiently administered and analyzed online, or using some type of technology. It is likely that some schools or systems do not have widespread technology infrastructure or access could be limited in their use of these approaches. Finally, we are cognizant of the fact that the tool should be designed to be used by educators and funders as well as researchers, which means that the burden of data collection and analysis will need to be low and the tool and materials simple to use. At the same time, the tool needs to be comprehensive and accurate if it is to inform the priorities and strategies of practitioners, community members, and the Foundation. As we describe in the next section, we attempted to balance these competing interests.

Tool Review Summary

Most of the existing tools for measuring SCL identified in our review were surveys. Other common instruments included interview protocols and practice guides. Observation and artifact rubrics, survey logs, and walkthrough instruments were less common. The most commonly measured constructs among the tools we reviewed, and which were related to our SCL strategies, included competency-based learning approaches and student agency; less common constructs measured through existing instruments we identified included data use and evidence related to contextual conditions at the district level or in the community.

As noted in our review, surveys can be an efficient way to gather information from a variety of stakeholders and impose limited burden for administration and analysis, and the validity of some of the surveys we reviewed is well documented. On the other hand, survey responses are self-reported and may suffer from reference and response biases. More direct measures of instruction like observation and artifact rubrics have the advantage of gathering rich information on instruction but represent considerable time burdens in terms of training and data analysis.

In addition, the tool review has brought to the forefront a number of challenges that are inherent to the measurement of SCL, including the difficulty of capturing the important—and often intentional—variations in SCL practices, the need to measure SCL implementation at many different grain sizes, as well as learning that occurs outside the classroom and school day, or through online software platforms. We are also aware of the need to balance burden of administration and analysis with capturing enough detail to ensure accuracy and inform next steps for implementation.

SECTION 5

SUMMARY OF REVIEW FINDINGS AND NEXT STEPS

The goal of this report was to lay the groundwork for the development of a set of instruments to gauge the extent of SCL practices, and supports for those practices, in classrooms and schools. As such, we proposed a conceptual framework including SCL strategies and contextual conditions that support SCL, and we reviewed both the research literature and existing instruments and measures related to those strategies and contextual conditions. Our review of the relevant literature and existing SCL measures helped us to determine those SCL practices for which to develop measures, as well as what resources and existing instruments might be available to help us with that measure development.

Summary of Literature Review Findings

We proposed five key SCL strategies, which are intended to serve as a working definition of SCL:

- 1. Learning is personalized to align with students' needs, interests, and pace.**
- 2. Learning is challenging, engaging, and meets students where they are in a competency-based system.**
- 3. Learning happens anytime, anywhere.**
- 4. Learning opportunities promote student agency and ownership.**
- 5. Learning is informed by data.**

These strategies emerged from our review of the research literature as intertwined with current assumptions and ideas about what is essential to SCL, according to both NMEF and many recent SCL programs and initiatives. These strategies implicitly involve both students and educators, with the assumption that the success of SCL programs depends on the deep involvement and work of both educators and students. These SCL strategies could therefore be regarded as both inputs implemented by educators and student outcomes and experiences.

Our review of literature related to SCL strategies indicates that some of them have a stronger empirical basis than others. As we noted early in this report, the development of stronger SCL definitions and measures could support more empirical research on the relationship between particular SCL strategies and outcomes. Specific aspects of our SCL strategies with the clearest support from the empirical literature connecting instructional practice to better student outcomes include:

- Personalization of content based on student interests;
- Competency- and mastery-based systems in which students have unlimited time to master specific learning targets or goals before moving on to new goals;

- Service-learning programs linking community service to classroom instruction; and
- Teaching metacognitive strategies that help students plan and monitor their own learning.

That said, much of the research emphasizes that such approaches can be implemented in ways that are highly variable and combined with other program features. And, at least some research also suggests mixed results for the implementation of the above approaches in some settings. These findings thus suggest that specific implementation features and choices may matter a great deal for the success of particular SCL programs.

Additionally, given that most SCL strategies represent a considerable shift from traditional approaches to schooling, the contextual conditions or context for SCL programs are likely important aspects of successful SCL program implementation. The key contextual conditions for implementation of SCL approaches and similarly ambitious reforms include committed leadership; a comprehensive, shared vision for reform; active partnerships with other stakeholders; a comprehensive, long-term adult learning plan; alignment among vision, policy, tools and professional development within the school system; and a commitment to quality assurance and continuous improvement. In addition, SCL reforms often require thoughtful and high-quality technological infrastructure and platforms to support online and digital learning. Research also suggests that contextual classroom learning conditions most likely to support SCL are those in which students perceive teachers to be respectful, caring, and supportive.

Summary of Tool Review Findings

We identified and reviewed 99 existing instruments that address the SCL strategies and conditions highlighted in our conceptual framework and the research literature. Most of the instruments we reviewed were surveys. It is perhaps unsurprising that surveys are so common as measures of SCL, given that they are typically easy and efficient to administer. Other common instruments we identified included interview protocols and practice guides. Observation and artifact rubrics, survey logs, and walkthrough instruments were less common. The most commonly measured constructs related to our SCL strategies included competency-based learning approaches and student agency; less common constructs measured through existing instruments we identified included data use and evidence related to contextual conditions at the district level or in the community.

Other key findings from our tool review are:

- Surveys covered a wide range of SCL practices in our conceptual framework, and the validity of some of those surveys is well documented. On the other hand, survey self-reports may suffer from reference and response biases, drawbacks other data collection methods may avoid. Surveys can also be limited by lack of generalizability in cases where response rates are low or the sample is not representative.

- More direct measures of instruction like observation and artifact rubrics have the advantage of gathering rich information on instruction but represent considerable time burdens in terms of rubric development and training for those who use the rubrics.

In addition, the tool review has brought to the forefront a number of challenges that are inherent to the measurement of SCL, including the difficulty of capturing the important—and often intentional—variations in SCL practices, the need to measure SCL implementation at many different grain sizes, as well as learning that occurs outside the classroom and school day, or through online software platforms. We are also aware of the need to balance burden of administration and analysis with capturing enough detail to ensure accuracy and inform next steps for implementation.

Tool Development

We drew on the instruments we collected, and guided by our proposed conceptual framework and five SCL strategies, created a usable tool to measure SCL implementation at the classroom and system levels—the Measuring Student-Centered Learning Toolkit. Our aim was to create a tool that could be used by educators and researchers to gauge the extent of SCL. As we described earlier in this report, each of the instruments we cataloged has advantages and drawbacks: measures that can be less burdensome to administer and analyze may not adequately capture the intentional variation in many SCL practices; on the other hand, more direct measures that may capture this variation can be cumbersome to administer and difficult to analyze. Furthermore, our literature review and advisory board feedback suggest it is important that the measures include the perspectives of many stakeholders, particularly students. Therefore, the Toolkit consists of a suite of measures—teacher, student, and administrator surveys, classroom walkthroughs, and an instructional log—designed to balance these competing priorities.

Although the instruments were designed for use in concert, we recognize that some users may wish to prioritize capturing some data on SCL from particular sources (e.g., student perspectives), so we designed instruments that could be used individually as well as in combination. In addition, each instrument is designed to capture practices, behaviors, and interactions related to each of the five strategies and contextual conditions to support SCL. Taken together, the Toolkit provides information on the extent of implementation of each strategy from the perspective of multiple stakeholders, thus allowing users to triangulate across the various data sources to create a comprehensive understanding of SCL implementation. This User Guide also includes guidance for analyzing and discussing the data and formulating next steps.

APPENDIX: SCL TOOL REVIEW

Table A.1 RAND-Identified Tools that Measure Aspects of SCL

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
1	Educator Competencies for Personalized, Learner-Centered Teaching	School Classroom Student	Competency-Based Learning; Personalized Learning; Student Agency; Staff Intrapersonal and Interpersonal Domain; Instructional Domain	Rubric	Staff ¹	Unknown
2	Guide to the Competency-Based Learning Survey for Students	School Classroom Student	Competency-Based Learning; Personalization; Flexible Assessment	Survey	Students	Available
3	Future Ready District Assessment	All Levels ²	Innovative Curriculum and Instruction; Assessment; Use of Space and Time; Technology, Networks, and Hardware; Data and Privacy; Community and Partnerships; Digital Learning Professional Development; Budget of Resources; Empowered, Innovative Leadership	Survey	District Leaders	Unknown
4	K-12 Online Learning: A 2008 Follow-up of the Survey of U.S. School District Administrators	All Levels	Online/Blended Learning	Survey	District Leaders	Unknown
5	Competency-Based Learning: Definitions, Policies, and Implementation	District School	Competency-Based Learning Implementation	Interview and Focus Group Protocols	Leaders ³	Unknown
6	Proficiency-Based Pathways Focus Group Protocol	School Classroom Student	Proficiency-Based Pathways	Interview and Focus Group Protocols	Students	Unknown
7	Big Picture: Learning Tools	Classroom Student	Career and Life Skills; Creativity and Innovation; Critical Thinking and Problem Solving; Communication; Information, Media, and Technology Skills	Practice Guide	Students	Unknown
8	Expeditionary Learning/Casco Bay Graduation Outcomes	Classroom Student	Problem Solving; Self-Accountability; Social Responsibility	Practice Guide	Students	Unknown
9	Checklist for Quality Assessment Plans	School Classroom	Quality Standards and Learning Targets; Motivating and Flexible Assessments	Practice Guide	Leaders	Unknown
10	Course Level Competency Validation Rubric	Classroom	Competency-Based Learning Standards and Assessments	Rubric	Staff	Unknown
11	The Study of Deeper Learning: Opportunities and Outcomes. Student Survey	School Classroom Student	Opportunities for Deeper Learning; Interpersonal and Intrapersonal Competencies; School Environment	Survey	Students	Available
12	The Study of Deeper Learning: Opportunities and Outcomes. Student Survey Documentation. Teacher Survey	All Levels	Instruction in Classroom and School; Students in School; Professional Development	Survey	Instructional Staff	Available

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
13	Competency-Based Education 360 (CBE260)	Classroom Student	Competency-Based Learning; Personalized Learning; Student Agency; Progress Monitoring; Student Goal Orientation; Peer Support for Academic Work; Supportive Learning; Student-Teacher Relationships; Anytime, Anywhere Learning; Digital Learning	Survey	Students	Unknown
14	Competency-Based Education 360 (CBE260)	School Classroom	Competency-Based Learning; Personalized Learning; Student Agency; Progress Monitoring; Student Goal Orientation; Achievement-related beliefs; Supportive Learning; Student-Teacher Relationships; Anytime, Anywhere Learning; Digital Learning	Survey	Teacher	Unknown
15	Effective Learning Environment Observation Tool	All Levels	Equitable Learning; High Expectations; Supportive and Active Learning; Progress Monitoring; Digital Learning	Observation Tool	School Leaders	Available
16	Patterns of Adaptive Learning Scales (PALS)	Classroom Student Community	Student Goal Orientation; Achievement-related beliefs; Parent and Community Life	Survey	Students	Available
17	Patterns of Adaptive Learning Scales (PALS)	School Classroom Student	School Goal Structure for Students; Goal-Related Approaches to Instruction; Personal Teaching Efficacy	Survey	Instructional Staff	Available
18	Global Best Practices: An Internationally Benchmarked Self-Assessment Tool for Secondary Learning Second Edition	All Levels	Teacher and Learning; Organizational Design; School and District Leadership	Rubric	Staff	Unknown
19	Future Ready Gear Assessment for Curriculum, Instruction, and Assessment	All Levels	21st Century Skills /Deeper Learning; Personalized Learning; Collaborative, Relevant, and Applied Learning; Leveraging Technology; Assessment Analytics Inform Instruction	Survey	District Leaders	Unknown
20	Future Ready Gear Assessment for Personalized Professional Learning	All Levels	Technology Professional Growth; 21st Century Skills /Deeper Learning; Participative Evaluation	Survey	Staff	Unknown
21	Future Ready Gear Assessment for Community Partnerships	All Levels	Community Engagement; Global/Cultural Awareness; Parent Engagement; District/School Brand	Survey	Staff	Unknown
22	Future Ready Gear Assessment for Robust Infrastructure	All Levels	Adequacy of Devices; Technology Infrastructure; Technology Review and Replacement	Survey	Staff	Unknown
23	Future Ready Gear Assessment for Space and Time	All Levels	Anytime, Anywhere Learning; Personalized Learning; Competency Based; Collaboration and Projects	Survey	Staff	Unknown
24	Future Ready Gear Assessment for Collaborative Leadership	All Levels	Digital Learning	Survey	Staff	Unknown

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
25	NGLC Student Survey	School Classroom Student	Post-High School Plans; Student Engagement and Motivation; Applied Learning; Study Habits; Supportive Learning; Personalized Learning	Survey	Students	Available
26	NGLC Instructional Staff Survey	School Classroom	School Infrastructure; Teacher Support; School Climate; Technology; Personalized Learning; Use of Data	Survey	Instructional Staff	Available
27	NGLC Instructional Staff Daily Log	Classroom Student	Classroom Instruction; Student Choice; Technology-Based Activities	Daily Log	Instructional Staff	Available
28	NGLC Administrator Interviews	School Classroom Student	School Vision; Personalized Learning; Competency-Based Learning; Curriculum and Technology-Based Learning; Student and Teacher Support	Interview and Focus Group Protocols	School Leaders	Available
29	NGLC brief protocol for observation of instructional practice	Classroom Student	Groups and Formation; Classroom Instruction; Student Engagement	Observation Tool	School Leaders	Available
30	NGLC Individual Interview, Principal Protocol	School Classroom Student	School and Classroom Staffing and Structure; Instructional Approaches; Competency-Based Learning	Interview and Focus Group Protocols	School Leaders	Available
31	NGLC Teacher Focus Group Protocol	School Classroom Student	Curriculum and Instruction; Personalized Learning; Competency-Based Learning	Interview and Focus Group Protocols	Instructional Staff	Available
32	NGLC Parent/Guardian Focus Group	School Classroom Student	Opinions About the School; Technology; Student Performance; Post-High School Plans and Preparation	Interview and Focus Group Protocols	Parents	Available
33	NGLC Student Focus Group	School Classroom Student	Technology; Personalized Learning; Competency-Based Learning; Post-High School Plans and Preparation; School Climate	Interview and Focus Group Protocols	Students	Available
34	Depth of Knowledge Levels	Student	Deeper Learning	Rubric	Staff	Unknown
35	Personalized Learning Student Observation	Classroom Student	Classroom Environment and Teacher; Balance of Rigor and Academic Ownership; Student Agency and Engagement	Observation Tool	School Leaders	Unknown
36	Spectrum of Student Voice	All Levels	Student Voice	Rubric	Staff	Unknown
37	The math and science engagement scale: Development, validation, and psychometric properties	Classroom	Cognitive Engagement; Behavioral Engagement; Emotional Engagement; Social Engagement	Survey	Students	Available
38	Adolescents' Perceptions of School Environment, Engagement, and Academic Achievement in Middle School	School Classroom Student	School Performance/Mastery Goal Structure; Support of Autonomy; Promotion of Discussion; Teacher Social Support; School Participation; School Identification; Self-regulation strategies	Survey	Students	Available

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
39	Getting Ready for the Common Core State Standards	School Classroom	Professional Development; Instructional Leadership; Teacher Collaboration and Influence; Common Core Standards	Survey	Instructional Staff	Available
40	Dilemma of Performance-Approach Goals	Classroom Student	Self-Regulation; Student Engagement and Motivation; SEL	Survey	Students	Available
41	Changes in the perceived classroom goal structure and pattern of adaptive learning during early adolescence	Classroom Student	Mastery/Performance Goal Structure; Self Efficacy; Personal Achievement Goals	Survey	Students	Available
42	Using Student Achievement Data to Support Instructional Decision Making	District School Classroom	Use of Data for Classroom and School-Wide Improvements	Practice Guide	Staff	Available
43	Analyzing Survey with Kids (ASK) Tool	All Levels	Student Voice	Interview and Focus Group Protocols	Students	Unknown
44	Inside-Outside Fishbowl Tool	All Levels	Student Voice	Interview and Focus Group Protocols	Students	Unknown
45	Students Studying Students' Stories Tool	All Levels	Student Voice	Interview and Focus Group Protocols	Students	Unknown
46	2016 Trends in Digital Learning: How K-12 Leaders are empowering personalized learning in America's schools	All Levels	Blended Learning	Survey	Leaders	Unknown
47	2017 CPS 5 Essentials Teacher Survey	Classroom Student	Effective Leadership; Collaborate Teachers; Family Engagement; Supportive Environment; Ambitious Instruction	Survey	Instructional Staff	Unknown
48	2015 CPS My Voice, My School Teacher Survey	Classroom Student	School Climate; Use of Data; Classroom Instruction; Leadership; Parent Engagement; Student Agency; Professional Development; Teacher-Parent Relationships; Quality of Student Discussion; Expectations for Postsecondary Education	Survey	Instructional Staff	Available
49	2015 CPS My Voice, My School Student Survey: 4th and 5th grade version	Classroom Student	Peer Support for Academic Work; Academic Press; Personalization	Survey	Students	Available
50	2015 CPS My Voice, My School Student Survey: 6th-12th grade version	Classroom Student Community	School/Classroom Climate; Student Emotional Health; Student Agency; Parent and Community Support; Classroom Instruction; Personalization; School-Wide Future Orientation	Survey	Students	Available
51	2015 CPS Administrator Survey	School Classroom	Teacher Evaluations; Common Core Standards; Professional Development; High School Choice; Use of Data	Survey	School Leaders	Unknown

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
52	Panorama Student Survey (6th - 12th grade)	School Classroom Student	Teaching Quality, School/Classroom Climate; School /Teacher Expectations; Student Engagement; Teacher-Student Relationships; Feelings of Belonging; Value of School/Subjects; School/Teaching Strategies; Student Mindset; Student Grit; School Safety	Survey	Students	Available
53	Panorama Student Survey (3rd - 5th grade)	School Classroom Student	Teaching Quality, School/Classroom Climate; School /Teacher Expectations; Student Engagement; Teacher-Student Relationships; Feelings of Belonging; Value of School/Subjects; School/Teaching Strategies; Student Mindset; Student Grit; School Safety	Survey	Students	Available
54	Panorama Teacher Survey	School Classroom Student	School Climate; Professional Learning; Teaching Efficacy; Feedback and Coaching; Staff-Leadership Relationships; School Leadership; Assessments; Student Agency; Staff-Family Relationships	Survey	Staff	Unknown
55	The LEAP Personalized Learning Teacher Surveys	Classroom Student	Personalized Learning; Competency Based; Student Agency; Flexible Environment	Survey	Instructional Staff	Unknown
56	The LEAP Personalized Learning Student Surveys	Classroom Student	Personalized Learning; Competency Based; Student Agency; Flexible Environment	Survey	Students	Unknown
57	Personalized Learning Lesson Template for a Lesson in Two 45-Minute Sessions: A Practice Guide	Classroom	Motivation to Learn; Metacognitive Competencies; Social and Emotional Competencies; Individualized, Differentiated, and Varied Instruction	Practice Guide	Instructional Staff	Unknown
58	ED School Climate Surveys: Student Survey	Classroom Student	School Climate; Safety; Environment	Survey	Students	Unknown
59	ED School Climate Surveys: Instructional Staff Survey	School Classroom Student	School Climate; Safety; Environment	Survey	Instructional Staff	Unknown
60	ED School Climate Surveys: Non-Instructional Staff Survey	School Classroom	School Climate; Safety; Environment	Survey	School Leaders	Unknown
61	Accountable Talk Observation Rubrics, 2003	Classroom Student	Academic Rigor; Clear Expectations; Self-Management of Learning; Accountable Talk	Rubric	School Leaders	Available
62	Accountable Talk Function Checklist, 2003	Classroom Student	Academic Rigor; Clear Expectations; Self-Management of Learning; Accountable Talk	Observation Tool	School Leaders	Available
63	Clear Expectation/Self-Management of Learning Observation Checklist, 2003	Classroom Student	Academic Rigor; Clear Expectations; Self-Management of Learning; Accountable Talk	Observation Tool	School Leaders	Available

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
64	Personal Competencies/Personalized Learning: Reflection on Instruction	Classroom	Standards-Aligned Learning Objectives; Personalized Learning; Technology; Cognitive Competencies; Motivational Competencies	Observation Tool	Instructional Staff	Unknown
65	Portland Student Questionnaire DLSC Phase 2 Year 1 - 2016	School Classroom	Classroom Instruction; School Environment, Adult Support; Anytime, Anywhere Learning; Technology	Survey	Students	Unknown
66	Portland Teacher Questionnaire DLSC Phase 2 Year 1 - 2016	School Classroom	SCL Implementation and Support; Student Learning Support; Proficiency-Based Assessments; Professional Development; Teacher Support; Instructional Practice	Survey	Instructional Staff	Unknown
67	Common Indicators for Systems-Level Change and College/Career Readiness	All Levels	Collaborative Culture; Personalization and Scaffolding; Equity; Deeper Learning; Post-Graduate Readiness and Success	Rubric	Leaders	Unknown
68	Hartford Public Schools Core Four Walkthrough Guide	All Levels	Integrated Digital Content; Data-Driven Decision; Small Group Instruction; Student Ownership and Reflection	Walkthrough	Students	Unknown
69	Knowledge Works Personalized Learning Self-Assessment	District	District's Vision for Personalization; Culture of Personalization within District; Level of Transparency in Teaching and Learning; District's Use of Personalized Learning	Survey	District Leaders	Unknown
70	SEL School Capacity Survey	School Community	Community Engagement; SEL Initiatives and Curricular Elements; SEL CounSELing Capacity	Survey	Leaders	Unknown
71	CASEL School Guide Tool 2.1: School Strengths Inventory	School Community	SEL Curriculum and Instruction; SEL School Practices and Policies; SEL Community Engagement	Practice Guide	Leaders	Unknown
72	SCUSD Middle/HS SEL Site Interviews	School Classroom	SEL Professional Learning; SEL Instructional Methods; Students Voice; Learning Environment and Partnerships that Promote SEL; SEL Leadership Team; Use of Data	Interview and Focus Group Protocols	Leaders	Unknown
73	SCUSD Elementary SEL Site Interviews	School Classroom	SEL Professional Learning; SEL Instructional Methods; Students Voice; Learning Environment and Partnerships that Promote SEL; SEL Leadership Team; Use of Data	Interview and Focus Group Protocols	Leaders	Unknown
74	CASEL Collaborating Districts Initiative Rubric/Benchmarks	School	Conduct Needs and Resources Assessment; SEL District Visions and Goals; SEL Experts; Align Needs and Resources to Support SEL	Rubric	Leaders	Unknown
75	K-12 Online Learning Survey	All Levels	Importance and Barriers of Blended Learning; Relationship with other organizations; Student Teacher Preparation for Success; Providers of Courses	Survey	Leaders	Unknown

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
76	K-12 Service Learning Standards for Quality Practice	Student	Meaningful Service Learning; Service Learning Linked to Curriculum; Service Learning Reflection; Service Learning Diversity	Practice Guide	Leaders	Available
77	Measuring Situational Interest in Academic Domains	Classroom Student	Student Engagement	Survey	Students	Available
78	Motivated Strategies for Learning Questionnaire	Student	Student Motivation; Student Self-Regulation	Survey	Students	Available
79	Problems in Schools (PIS) Questionnaire	Classroom	Supportive Classroom Instruction	Vignettes	Students	Available
80	Community-Based Learning Assessment Rubric	Student	Service Learning Communication; Service Learning Problem Solving; Service Learning Personal Development; Service Learning Social Responsibility	Survey	Leaders	Unknown
81	Changing Systems to Personalized Learning: Personalized Learning	All Levels	Student Engagement; Flexible Pathways	Practice Guide	Leaders	Unknown
82	Changing Systems to Personalized Learning: Power of Advisories	All Levels	Personalized Learning Mentorship	Practice Guide	Leaders	Unknown
83	Changing Systems to Personalized Learning: Teaching to Each Student	All Levels	Personalized Learning Instructional Methods	Practice Guide	Leaders	Unknown
84	Measures of teacher-student relationships, effortful engagement and achievement	Classroom Student	Student-Teacher Relationship; Student Engagement	Survey	Instructional Staff	Available
85	MNPS SEL Walkthrough 2016-2017	School Classroom	SEL School-Wide Environment; SEL Classroom Instruction; SEL Classroom, Environment, Management, Discipline	Walkthrough	Staff	Unknown
86	CASEL-AIR Staff Survey of SEL Implementation	School	SEL Vision, Needs and Resources; SEL Professional Development; SEL Implementation; SEL Integration; SEL Continuous Improvement	Survey	Staff	Available
87	Discussing Reform: Tools for Facilitating a Focus Group	All Levels	Understanding and Implementation of Reforms; State Roles and Strategies in Scaling Up Reforms; Support System for Reform; Standards and Assessments	Focus Group Protocol	State Leaders	Unknown
88	Looking Under the Hood of Competency-Based Education: The Relationship Between Competency-Based Education Practices and Students' Learning Skills, Behaviors, and Dispositions	All Levels	Learning Targets; Measurement of Learning; Flexible Pacing and Progression; Assessment of Learning; When/Where Learning Happens; Individualized Instruction and Support	Survey	School Leaders, Staff, Students	Unknown
89	Classroom Assessment Scoring System	Classroom Student	Emotional Supports; Classroom Organization; Instructional Supports	Observation	Staff	Available
90	Best practices in teaching K-12 Online: Lessons learned from Michigan Virtual School teachers	Classroom Student	General Characteristics of Online Learning; Classroom Management Strategies; Assessments; Engaging Students with Content; Making Course Meaningful for Students; Providing Support; Communication & Community; Technology	Interview and Focus Group Protocols	Instructional Staff	Available

	Title	Focus Area	SCL Constructs	Instrument Type	Respondent Group	Reliability/Validity Information
91	Competency-Based Education in Three Pilot Programs: Examining Implementation and Outcomes	Classroom Student	Student Experience with Curriculum Materials; Study Habits; Student Engagement; Post-Secondary Plans	Survey	Students	Available
92	Competency-Based Education in Three Pilot Programs: Examining Implementation and Outcomes	School Classroom	Competency-Based Accomplishments; Defined Progressions toward Mastery; Anytime/Anywhere Learning; Credit for Mastery; Insights from Implementation	Interview and Focus Group Protocols	Leaders	Available
93	Progress and Proficiency: Redesigning Grading for Competency Education (CompetencyWorks Issue Brief)	Students Classroom	Scoring Scale for Academic Learning; Scoring Scale for Lifelong Learning Standards	Rubric	Staff	Unknown
94	Equity in Competency Education: Realizing the Potential, Overcoming the Obstacles	Student Classroom	Competency-Based Learning Benefits, Barriers, and Implementation; Equity Concerns	Interview and Focus Group Protocols	Leaders	Unknown
95	Deeper Teaching	Student Classroom	Deeper Teaching	Practice Guide	Staff	Unknown
96	Personal Opportunity Plans	Student Classroom	Instructional Approaches; Workshops and Activities; Flexible Personnel Structure; Scheduling Accommodation's; Timely Communication; Effective Professional Learning; Assessment and Accountability; Shared Responsibility	Practice Guide	Leaders	Unknown
97	Blended Learning Report	School Classroom	Infrastructure and Technology; Teacher Training and Support; Software Design Elements; Benefits to Teaching and Learning; Student Productivity; Impacts of Blended Learning	Survey	Instructional Staff	Unknown
98	Student-Centered Schools: Closing the Opportunity Gap	School Classroom	Classroom Instruction; Leadership; Teacher Professional Development; Teacher Collaboration; Role as a Teacher; Student Support; Student Engagement; Parent and Community Engagement	Survey	Instructional Staff	Unknown
99	Student-Centered Schools: Closing the Opportunity Gap	School Classroom	Classroom Instruction; Student Engagement; Teacher Support; Groups and Formations; Student Support; School Inclusion; Post-High School Plans; Family Engagement	Survey	Students	Unknown
100	Student-Centered Schools: Closing the Opportunity Gap	School Classroom	Post-High School Achievements; College Class Experience; Student Engagement; Family and Community Engagement; College Affordability; College Preparedness	Survey	Student Graduates	Unknown
101	First Response: A guide to designing and delivering classroom interventions	School Classroom	Classroom Instruction; Use of Data; School Culture	Interview and Focus Group Protocols	All Levels	Unknown

APPENDIX: SCL TOOL SOURCES

These reference numbers correspond with the order in Table A.1 above.

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