A Commitment to Equity:
The Design of the UDL Innovation Studio at the Schwab Learning Center

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Even the self-assured will raise their perceived self-efficacy if models teach them better ways of doing things. Albert Bandura

Equity, Barriers and Innovation

Between 2000 and 2016 the total postbaccalaurete enrollment increased from 2.2 million to 3 million students (McFarland et al., 2018). With this growth the face of higher education is more diverse than ever before. Colleges and universities are faced with a growing number of individuals with disabilities, older adults who return to college or who enter for the first time, those who live in poverty, first generation students, and individuals who are diverse with respect to race, ethnicity, and gender. Some may lack the support system or academic capital needed to navigate higher education, despite their motivation. For example, a study by the National Alliance on Mental Health in 2012 reported 64% of young adults who are no longer in college, are not attending college because of a mental health related reason, but more than 45% of these students did not request disability-related accommodations. To compound this issue, individuals with mental health challenges are one of the fastest growing groups in postsecondary institutions. Academically competent individuals who present with a variety of learning challenges are on the rise throughout the world creating pressure in society to both break down and uphold barriers to higher education and meaningful work. These barriers to higher education include costs to both the student and the school, cultural notions of disability and gender, stereotype threats, and the inability to access the health and academic resources to enter and complete higher education.

Professionals in higher education who recognize the value of a diverse workforce are looking for ways to ameliorate the impact of these barriers by changing how we teach and prepare students in higher education for the workforce. Their objectives are to (a) increase retention in prerequisite coursework and college completion, (b) improve teaching for all learners, (c) promote expert learning and maximize engagement in the classroom, and (d) reduce the need to provide disability related classroom accommodations by teaching with all learners in mind. For these individuals much of the drive to break down barriers to successful completion of higher education stems from both a social justice perspective and dedication to the fiscal commitment and retention of students who are admitted to their institutions. A noble goal, given that older adults and those who are racially and ethnically diverse attend private, for-profit postsecondary institutions more often than public and not-for-profit institutions (McFarland et al., 2018). For some advocates interest in new ways of teaching simply stems from the rewards of teaching and desire to create an engaging classroom.

Still others feel pressure by the growing diversity in higher education and wittingly and unwittingly uphold these barriers because of (a) the administrative burden of time, space, and personnel to oversee disability-related accommodations, (b) the cost to the institution to provide legally mandated student services, (c) a school's mission to prioritize research over teaching, and (d) little awareness of how the mind and brain are associated with classroom and test-taking performance (i.e. the neuroscience and socio-cognitive aspects of learning). As the diversity in the number of individuals in higher education rises, both the desire and resistance to change how we prepare students increases in tandem.

This tension around how to meet the growing diversity in higher education detracts from the value these individuals have in society and the meaningful contributions they bring to educational and work environments. Moreover, changes in the learning environment are rarely the manner in which faculty and administrators in higher education attempt to support these diverse populations. Support is usually external through community centers dedicated to race and culture, or campus centers for health, counseling, and disability. Without a systematic way to interrupt current practice in the classroom the impact of these barriers is repeatedly faced by each generation without significant forward motion to break the cycle once and for all. These barriers pose multiple threats to social justice, academic and social capital, and health equity.

Colleges and universities throughout the world need exemplars of innovative practices to adapt and expand their pedagogies so that they can serve the widest range of students possible, including those that are presently excluded and at risk for dropping out or graduating with suboptimal learning and capital. To meet our goal of systemic change with the greatest impact, we partnered with CAST the home of Universal Design for Learning (UDL) to create a model UDL Innovation Studio for higher education. Through this partnership, we collaborate and innovate in ways that can change the learning environment to improve the quality of the learning experience for all students, not only at Stanford University but also at postsecondary institutions around the world. Studio participants are inspired by strategies that include the full range of individuals in their teaching, learning, and projects. Through working with faculty, researchers, and staff, our intent is to improve the quality of learning and instruction, as well as retention rates in order to prepare all individuals to live equitably and meaningfully across the lifespan. By working with university students we intend to prepare thought leaders who can advance social justice and promote equity across the lifespan.

Universal Design for Learning
Universal Design for Learning (UDL) is a framework for understanding human variability and for designing learning environments and tools that proactively plan for and facilitate "cognitive and psychological access" to learning (Ok, Rao, Bryant, & McDougall, 2017, p. 116). The UDL framework draws on cognitive, neurological, and learning sciences research and details the interrelationships between recognition, strategic, and affective networks in the brain (Meyer, Rose, & Gordon, 2014). The framework is organized around three interdependent principles of providing multiple means of representation, expression and action, and engagement so as to amplify learner capacities and minimize barriers to learning (Meyer, Rose, & Gordon, 2014). Barriers can range from a one-size-fits-all summative assessment to a video unavailable with close captions. The three principles are detailed with checkpoints in the UDL Guidelines 2.0 (www.cast.org). Articulated in the framework is the tenet that learner variability is the rule and abilities are context-dependent (Meyer, Rose, & Gordon, 2014). Challenges arise through the interaction between the learner and the environment. Many educational practices ignore variability focusing on a sometimes mythical "typical learner."

Although UDL was conceived of in the 1990's, application of UDL principles in higher education is relatively new but growing. In fact, EDUCAUSE, a nonprofit association whose mission is to advance higher education through the use of information technology, recently identified accessibility and universal design as the second most critical issue facing higher education in 2018 (EDUCAUSE, 2018). In addition, UDL practices have been promoted in national education policies such as the Higher Education Opportunity Act, the Individuals with Disabilities Education Act, and the Every Student Succeeds Act.

The UDL Innovation Studio, in partnership with CAST at Stanford University is a portable "pop-up" learning hub where participants collaborate to examine and develop tools and instructional practices for educating all students, especially those who are underserved and marginalized by traditional methods and materials. The UDL Innovation Studio was conceived to address the growing diversity in higher education by harnessing the user experience to drive effective solutions to reaching the broadest population of individuals using multiple means of representation, expression and action, and engagement. At the Schwab Learning Center's studio, our "user" participants are students, faculty, researchers and staff (e.g. clinicians, educational designers). Participants can come to the Studio with a variety of purposes, for example, an interest in designing technology or tools along the principles of UDL, course redesign, or a simple question about an assessment or retention. The UDL Studio Manager and team meet participants where they are with a toolbox of idea generating supplies such as the UDL Guidelines, colored sticky notes, fidgets, markers and other ways to cultivate expression and innovate ways to increase The principal goals of the UDL Innovation Studio are:

- to investigate and deeply understand the lived experiences of a range of students in higher education;
- to innovate new practices and tools to support all learners in cooperation with Stanford students and faculty;
- to model and disseminate new knowledge about UDL implementation in higher education and the workforce; and

- to prepare all students for successful transition into the workforce and society.

In service of these goals, the UDL Innovation Studio prioritizes learning *from* and *with* its participants to design curriculum, assessments, and instructional strategies that are flexible, supportive and appreciative of learner variability, and, most of all, strengths-based. We do this through working with faculty, researchers and staff, on course redesign, identifying UDL solutions to specific aspects of a course or program of study and the emerging UDL Studio Classroom which will be a classroom designed to model UDL and co-teach courses with faculty. Our work with students involves harnessing the range of user experiences to design tools, technology and apps using the UDL Guidelines. Our aim is to drive solutions to course redesign based on cognitive demands, engagement, motivation and choice as experienced by students.

Design Thinking in the Innovation Studio

To realize the UDL Innovation Studio's goals, four research-based processes and approaches to learning and design were adopted: cognitive labs, evidence-centered design (ECD), iterative design, and problem-based learning. These processes were adopted to provide guidance and inform the ways in which the UDL Innovation Studio learns *from* and *with* students and faculty. The question or need a participant brings to the Studio determines which process is employed. Under the direction of a UDL Studio Manager experiences and needs are uncovered and incorporated into UDL solutions to increase access to learning or design with the broadest population in mind. This paper describes the four processes in detail. Next, the commonalities and differences among the four processes are surveyed. The paper concludes with implications for how the UDL Innovation Studio employs or tends to employ these research-based processes to accomplish its goals.

Cognitive Labs

Cognitive labs, also known as think-alouds, have been used in the field of psychology as a way to understand a person's development of thought (Johnstone, Bottsford-Miller, & Thompson, 2006). A cognitive lab is a procedure whereby an individual is asked to complete a task, while simultaneously verbalizing the cognitive processes that are engaged. These verbal reports provide insights into the subject's mental processes and have been described by Karl Duncker (1945) as "productive thinking." In addition to collecting data on what the subjects verbalize aloud, during cognitive labs, the subject's physical and affective behavior are observed and noted. The disadvantages of cognitive labs, observed by some researchers, are that the verbalizations may be incoherent (Ericsson & Simon, 1993) and that for some subjects, the cognitive load of problem-solving and speaking simultaneously may be too difficult (Branch, 2000). Therefore, Branch (2000) suggests conducting retrospective interviews after the cognitive lab process is complete in order to mitigate the issue. In addition, research has shown that the level of task difficulty affects whether useful information is yielded from cognitive labs (Leighton, 2004). Overly simple tasks do not translate well to verbal reporting because the problem solving happens too quickly or automatically leaving the subject unaware of how the problem was solved and therefore, unable to verbalize the processes involved (Wilson, 1994). Tasks that are too complex or difficult have been found to overload subjects' working memory and negatively influenced subjects' abilities to articulate their problem solving processes (Taylor

& Dionne, 2000; Leighton, Gierl, & Hunka, 2004). Therefore, ideal tasks to be used in cognitive labs should be those that are of moderate difficulty, are novel, and require multiple steps for their solution such as the experience of a student learning a new concept or process.

Since its conception in the field of psychology, cognitive labs have been applied to research in many different fields such as survey development (Camburn, Correnti, & Taylor, 2000; Sudm anan, Bradburn, & Schwarz, 1996), assessment design (Johnstone, Bottsford-Miller, & Thompson, 2006; Leighton, 2004; Willis, 1999), reading (Pressley & Afflerbach, 1995), and technology (Hughes & Parkes, 2003). For example, Winter, Kopriva, Chen, and Emick (2006) used cognitive labs to examine the interactions between individual student characteristics and test item factors and its effects on assessment validity for diverse students, including English Language Learners. They found that students' verbalizations provided valuable insights into how specific construct-irrelevant item features interacted with individual student characteristics and mediated student performance on math problem solving items. Specifically, students who had difficulty comprehending the task requirements because of language demands or lack of background knowledge were less likely to formulate correct solution strategies. In this case, the use of cognitive labs provided evidence of how students' access to item content could be limited thereby decreasing the validity of the assessment.

Cognitive labs procedure. To conduct cognitive labs, a subject is presented with a task or activity and instructed to read the task question or directions and the answer choices (if it is a selected response item) out loud. The subject is told to express all thoughts out loud while answering the question or engaging in the activity. The researcher takes notes on the subject's responses and utterances as the subject is thinking aloud. If the subject is silent for 5 sections, the researcher prompts the subject by asking questions such as "What are you thinking now?" "Keep talking." "Tell me more about what exactly you are thinking about." After the completion of the task or activity, researcher may conduct a retrospective interview to elicit more information about the subject's internal processes (i.e., have the subject clarify or elaborate his responses) or evaluate his experience of the task or activity. In the retrospective interview, follow up questions are posed to the subject such as "What strategy did you use to solve the problem?" "Tell me what you were thinking when you said X." "How hard/easy was this task for you?" "What made this task easy/hard for you?" "Was this task interesting to you; why or why not?" "Was there anything that confused you?" For example, a faculty member can have a group of students watch a video of a particular concept being taught as it might be in a class. During the video a researcher or facilitator elicits students' engagement, understanding, and interaction with the process of learning. While each student watches they can describe their thinking about the process which may involve task or cognitive demands such as note-taking, working memory, cognitive load, copying from a screen to notes, pace, or academic language. A student might relate the moment in a lecture when the information became confusing. After the video, a short test that emulates what might be given in class is administered and again students can express how they are interacting with the test and how the test relates to the lesson taught in the video. Collectively students can generate ideas to make the content more meaningful, accessible and foster deeper learning.

Evidence-Centered Design
Evidence-Centered Design (ECD) is a framework for designing and delivering educational instruction, assessments, and materials and is the most sophisticated process of the four. It is most often used to development an assessment that is as authentic and valid as possible. It's roots derive from developments in fields such as expert systems, software design, and legal argumentation (Haertel, DeBarger, Villalba, Hamel, & Colker, 2010). Evidence-Centered Design emerged from a project at the Educational Testing Service intended to provide "a conceptual design framework for the elements of a coherent assessment, at a level of generality that supports a broad range of assessment types" (Mislevy, Almond & Lukas, 2003, p. 1). The ECD design process defines an assessment as an evidentiary argument from which observations of what students say, do, and make are made as well as inferences about what they know, can do, or have accomplished (Mislevy, Steinberg, & Almond, 2003). The goal of the ECD is to ensure that the way in which evidence of competence is gathered and interpreted is consistent with the purpose of the assessment (Mislevy, Almond & Lukas, 2003). Given that competence is regularly measured in higher education with summative assessments of content, there is little evidence that assessments are valid predictors of performance in the workforce. Application of ECD and UDL to assessment in higher education is especially timely as a growing number of researchers and organizations note that college graduates are not prepared for a 21st century workforce (Burrus, Jackson, Xi & Steinberg, 2013; Markle, Brenneman, Jackson, Burrus & Robbins, 2013). Incorporating UDL solutions in ECD provides the opportunity for all students to have the opportunity to demonstrate competencies employers seek such as leadership, creativity, critical thinking, teamwork, effective communication, digital and information literacy, citizenship, and executive functions such as time management, goal setting, and social skills (Oliveri & Markle, 2017; Shechtman, Yarnall, Stities, and Cheng, 2016). The principles of UDL simultaneously promote all of these competencies through its inherent design.

ECD procedure. This procedure is best conducted by a group of faculty or teaching staff from the same domain or field of study. ECD organizes the work of instruction and assessment design into five layers: domain analysis, domain modeling, conceptual assessment framework, assessment implementation, and assessment delivery. In the **domain analysis** layer, substantive information about the domain to be assessed is gathered such as information about the concepts, terminology, representational forms, and ways of interaction in the particular domain. Domain analysis explicates the knowledge people use in a domain, the representational forms, characteristics of good work, and features of situations that evoke the use of valued knowledge, procedures, and strategies. Test developers gather and study relevant learning sciences research, solicit input from subject matter experts, and review previous tests, assessment tasks, scoring rubrics, and scales to inform the assessment design. This rich documentation increases task comprehensibility, precision, and reliability.

In the **domain modeling** layer, the information and relationships discovered in the domain analysis is organized and the assessment argument is expressed in narrative form. Domain experts, teachers, and designers work together to elucidate what an assessment is meant to measure, and how and why it will do so. This is a critical piece to helping faculty clarify what the goals of a course or program of study are, and how to assess those outcomes. Tools used in this layer are based on “big ideas” from a given domain. Domain modeling explicates the relationships between the assessment claims (e.g., focal knowledge, skills, and abilities (KSAs) targeted by the assessment, and additional KSAs), the data (i.e., important features of the tasks such as the goals, constraints, resources, stimulus materials), and the warrant (i.e., reasoning or rationale that explains why particular data provide evidence for the claims). At this stage, design patterns for the assessment are created to help faculty in specific domains “fill in the slots” to define the big ideas of the domain. Design components include:

1. Rationale – describes the nature of the KSAs of interest and how they are manifested, and articulates the connection between the data collected and the claims to be made
2. Focal KSAs – the primary KSAs targeted by the design pattern
3. Additional KSAs – other KSAs that may be required by tasks written under this design pattern
4. Potential Work Products – some possible things one could see students say, do, make that would provide evidence about the KSAs
5. Potential Observations – features of the things that students say, do, or make that constitute the evidence (e.g., potential rubrics)
6. Characteristic Features of Tasks – aspects of assessment situations in which students act and produce work products; central to evoking evidence about the focal KSAs (i.e., construct relevant task features)
7. Variable Features of Tasks – aspects of the assessment that the assessment designer can use to moderate the difficulty level or the focus of attention (e.g., manipulate variable features to reduce or eliminate demands for additional KSAs in which there are deficits while making sure not to change demands for focal KSAs)

The **conceptual assessment framework** (CAF) layer involves the technical specifications for the assessments (e.g., task features, measurement models, stimulus material specification, scoring methods, delivery requirements) and comprises three models:

1. Student Model expresses what the faculty is trying to measure in terms of variables that reflect aspects of students’ proficiencies. A thoughtful consideration of the UDL Guidelines intentionally allows for multiple means of expression.
2. Task Model describes the environment in which students say, do, or make something to provide evidence. A key design decision is specifying the form in which students’ performances will be captured (e.g., will the work product be multiple choice item, essay, sequence of steps in an investigation). The assessment designer (i.e. faculty) also specifies the forms and the key features of directives and stimulus materials and the features of the presentation environment (e.g., what resources must be available to the test taker, or what degree of scaffolding can be provided to the student).
3. Evidence Model bridges the student model and task model. Two components comprise the Evidence Model:
    a. Evaluation component – how salient aspects of student work are identified and evaluated in terms of values of Observable Variables. Evaluation procedures can be algorithms for automated scoring procedures, or rubrics, examples and training materials for human scoring.

b. Measurement model component – synthesizes the data generated in the evaluation component across tasks.

In the **assessment implementation** layer, all of the operational elements specified in the CAF including authoring tasks, finalizing scoring rubrics or automated scoring rules, estimating the parameters in measurement models, and producing fixed test forms or algorithms for assembling tailored tests are constructed and prepared. The ECD approach ensures that the rationales for each activity are directly linked back to the assessment argument.

Finally, in the **assessment delivery** layer, students interact with the assessment tasks, their performances are evaluated, and feedback and reports are generated. The value of ECD is that it makes connections within the assessment design and instructional delivery process explicit. ECD guides planning and coordinates work in developing tasks by laying out the assessment argument, clarifying design choices, and coordinating the development of operational elements. This evidence-based approach strengthens the interpretation of the scores produced by the test and the test designer has greater confidence that the inferences made about what a student knows and can do are valid.

In addition, equally important is the identification of additional KSAs that may be required of students when learning about a domain but are not construct-relevant or the long-term outcomes of interest (focal KSAs) during the domain modeling layer. The identification of the additional KSAs can provide teachers with flexibility in the curriculum, to plan for learner variability, so that gaps in students' related knowledge can be ameliorated or supported by the classroom teacher. The variable features, articulated in domain modeling, can take the form of scaffolds used to ensure that the instructional content is accessible to all students (e.g., use of multiple representations in instruction to make key concepts more prominent such as providing vocabulary support, demonstrations of processes, or contrasting cases).

Assessment tasks and items created through the ECD approach could be followed up with cognitive labs conducted with a variety of students (e.g., with high, medium, low levels of achievement) to ensure that the desired evidence of competence is being elicited by the items and tasks as planned. By examining the thinking of these different groups of students, insights into how the tasks perform both in terms of cognitive difficulty and engagement may be elicited. Moreover, through the use of cognitive labs, information about students' level of interest, anxiety, enjoyment, and frustration may be documented and examined, which can inform judgments about which items are appropriate for which grade level.

Iterative Design

Design has been the cornerstone of the engineering profession and iteration is considered to the be an integral part of the design process (Adams & Atman, 1999). Researchers at CAST use the iterative design process throughout all of their work on research and development in large part because it continually cycles back to the user experience. Iterative design is a design methodology based on a cyclical and recursive process of idea generation, evaluation, and design improvement (Wong & Park, 2010). Iterative design addresses design problems that are ambiguous with multiple solutions and are insufficiently solved by linear problem solving methodology (Wong & Park, 2010). Through the iterative design process, one's understanding of the problem evolves as more information is gathered and filtered during the stage of generating and evaluating possible solutions. In addition, new constraints, ambiguities, and contradictions are revealed during those activities, which then leads to revised problem scoping and improved design solutions. This is typically a fun and engaging process for faculty and students when coupled with UDL. When the UDL principles are introduced to students, faculty and staff as part of the iterative design process, an array of options for instruction and assessment appear that usually have not been considered.

Adams and Atman (1999) define iteration as a "goal-directed, non-linear process that utilizes heuristic reasoning processes and strategies to gather and filter information about the problem, and to inform the revision of possible solutions" (p. 1). From the perspective of cognitive theory, iterations can be viewed as cognitive processes that occur as design tasks are undertaken (Ullman, Wood, & Craig, 1990 cited in Adams & Atman, 1999). Moreover, information processing theories posit that iterations can be considered as reasoning processes that transform inputs, which are the information processing activities that gather and filter information about the problem and the solution, and inform the analysis, synthesis and evaluation of design solutions, into outputs, the decision activities that lead to changes in the design state or decisions to change or elaborate how the problem is represented or possible solutions. Thus, iterations are design decisions that affect the understanding of the problem, the modification or generation of solutions, and the design process itself. In this manner, the iterative design process provides a window into the designer's thought processes and problem-solving abilities.

Iterative design process. The iterative design process begins with the initial problem formation phase, which reflects the designer's current understanding of a problem (Adams & Atman, 1999). As the search for information to understand and solve the problem expands, the designer gains insight, which informs previous apprehensions and helps generate potential solutions. This process is recursive and improvements are made incrementally until the designer arrives at a final solution that meets the design criteria of the initial problem (Adams & Atman, 1999).

Another key feature in iterative design process is the constant elicitation of user feedback, during all phases of the design, development, implementation, and evaluation stages (Stone, Kent, Roscoe, Corley, Allen, & McNamara, 2018). The focus on the user is critical. Feedback during the design implementation or evaluation phase can initiate a design review and lead to additional modifications. For example, designers can conduct focus groups and observations with end users to determine their perceptions of system features and interface design, users' overall impressions of the product, their beliefs and attitudes regarding the new tool or product. Soliciting user feedback works to ensure that the designed product is responsive to users' needs and increases the likelihood that implementation of the design solution is successful and sustainable. The iterative design process has now become well-known in technology, engineering, and education as a way for designers, or in our case faculty and students, to empathize with others and shift perspective to that of the unique qualities of individuals. This is an important dimension in meeting the needs of diverse learners in higher education. To have the opportunity to engage with, for example, first generation students, non-native speakers of English, or students with disabilities and hear about their lived experiences in a learning environment or interaction with a piece of technology can be illuminating and powerful enough to motivate change.

Problem-Based Learning

Problem-based learning (PBL) is an instructional approach that organizes students to work collaboratively to solve complex and authentic problems (Problem-Based Learning, 2001). At a time when 21st century job skills require collaboration and social interaction skills more than ever (Shechtman, Yarnall, Stities, and Cheng, 2016), PBL is a powerful technique that can be used to both foster these skills and drive powerful solutions using UDL. Medical schools have used PBL since the early 1950s and 1960s to teach students clinical reasoning and problem solving skills in clinical practice by wrestling with complex patient case histories (Allen, Donham, & Bernhardt, 2011; Problem-Based Learning, 2001). The roots of PBL, however, extend even further in history to John Dewey, whose Lab School was based on the process of inquiry and situated learning. Dewey posited that "children will develop personal investment in the material if they engage in real, meaningful tasks and problems that emulate what experts do in real-world situations" (Krajcik & Blumenfeld, 2006, p.318). This notion of situated learning is drawn from learning sciences research that has shown that the most effective learning occurs when it is situated in an authentic, real-world context (Krajcik & Blumenfeld, 2006). Therefore, an example of situated learning in the UDL Innovation Studio would involve students exploring how to design multiple means of assessment for a particular physics concept while they engage in scientific practices such as devising investigations, making explanations, modeling, and presenting their ideas to others.

PBL begins with the assumption that learning is an active, integrated, and constructive process influenced by social and contextual factors (Barrows, 1996 cited in Problem-Based Learning, 2001), again all critical skills for today's workforce. Deep understanding occurs when a learner actively constructs meaning based on his experiences and interaction in the world (Krajcik & Blumenfeld, 2006). Introducing the UDL Guidelines in problem-solving, learners actively build knowledge as they explore the surrounding world, observe and interact with phenomena, take in new ideas, and make connections between new and old ideas. In PBL, students actively construct their knowledge by participating in real-world activities similar to those that experts engage in, to solve problems and develop artifacts. In concert with faculty, students can identify topics that are of most interest to them but essential to the program of study, establish their learning goals, help plan the classes, lead class discussions, and assess their own work and their classmates' work through multiple means of expression and assessment (Gallagher, 1997; Reynolds, 1997; UDL Guidelines 2.0, CAST). By emphasizing learning by doing, PBL engages students metacognitively. Through PBL, students become aware of what they already know about the problem, what they need to know to solve the problem, and strategies to solve the problem (Gijselaers, 1996 cited in Problem-Based Learning, 2001). Engagement is maximized by guiding PBL in solutions derived from the UDL Guidelines especially as they pertain to the principle of Engagement.

Group work is also a key aspect of PBL. Social interaction plays an important role in learning (Collins, 2006; Greeno, 2006). Learning occurs best when students work together to construct shared understandings and make meaning of the world around them. Through sharing, using, and debating ideas with others, learners develop understandings of principles and ideas (Blumenfeld, Marx, Krajcik, & Soloway, 1996). In addition, group work helps to develop a learning community, enhances students' communication skills, and can increase students' motivation since each student is held accountable for their actions and individual contributions to the final product (Krajcik & Blumenfeld, 2006). The group nature of PBL provides a powerful way to bring diverse learners into group dynamics while valuing all perspectives and experiences thus promoting empathy and reducing the likelihood of stereotypes threats, which is an important goal of UDL. Finally, the combined frameworks of PBL and UDL emphasize depth rather than breadth of content coverage, a competency in demand by today's employers. In a classroom setting, students are generally provided two to six weeks to work on the problem (depending on the complexity), but in the UDL Innovation Studio PBL can involve a variety of timeframes.

PBL procedure. PBL begins with the identification of a driving question or ill-structured problem that is authentic or has real-world applicability and is of interest to students. Next, collaborative student groups are formed and together, students identify and organize their prior knowledge and relevant ideas. In order to prepare all learners in higher education to be experts who are competent in today's workforce student groups should be made up of as wide a range of learners as possible. Then students research and explore the question or problem by reading, summarizing, comparing and contrasting, and integrating various sources of information. The instructor facilitates students' learning by providing context for the problem and clarifying students' misconceptions and provides ongoing feedback. Students collectively design a solution to the question or problem such as a written, oral, or visual presentation or artifact that is shared with their peers and others.

Discussion

The four design processes share notable similarities with different emphases on the UDL Guidelines. As illustrated in Figure 1, ECD and iterative design provide multiple check points throughout the design process to refine and revise solutions which allows for implementation of the most pertinent aspects of UDL to the question brought to the Studio. In addition, both iterative design and cognitive labs provide insights about the designer or subject's reasoning processes, which promotes many critical elements of UDL such as self-awareness, self-efficacy, motivation and expert learning. As a student or faculty member iterates the design solution, each modification or edit to the design can be viewed as an elaboration of the understanding of the problem and solution. Schön (1984) called this reflection in action. Similarly, a subject's verbalizations during a cognitive lab elucidates how the problem is understood or interpreted, what strategy is chosen to complete the task, and how the problem is ultimately solved. For students with learning differences this can uncover critical elements of information processing such as verbal retrieval, working memory, and executive functioning.

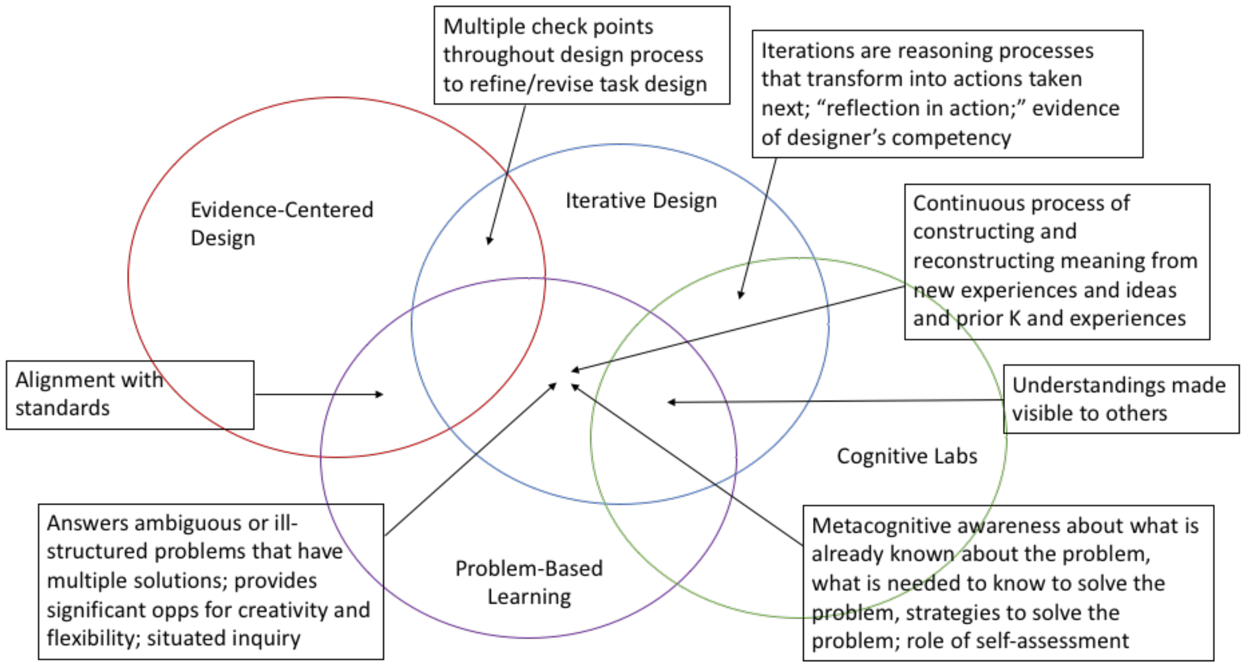

Figure 1. Similarities between the four design processes.

Multiple commonalities surfaced between PBL and iterative design procedures. For one, both typically begin with ambiguous or ill-structured problems that have multiple solutions to them. These approaches provide flexibility and opportunities for creative, out-of-the box thinking by Studio participants. Additionally, PBL, cognitive labs, and iterative design use authentic, real-world problems as the context for problem solving. As participants engage in these processes, they are continuously constructing and reconstructing meaning and ideas in connection with their prior knowledge and experiences. Moreover, PBL, cognitive labs, and iterative design include a metacognitive component as students must be self-aware in order to choose a viable reflect or drive solutions, or both.

Finally, at the nexus of PBL, iterative design, and cognitive labs was the way in which all three processes made a student's understandings visible to others. In cognitive labs, a student's verbalizations provide a window into her thinking or understanding. In PBL and iterative design, the evolution of the design artifacts and products are external representations of students' constructed knowledge. This allows for Studio participants to genuinely understand how best to apply UDL to their own context or domain, while also clarifying and meeting the needs of diverse learners.

The review of the design processes also revealed important differences between them regarding the purpose or driving questions that each process affords (see Figure 2). As an example, cognitive labs main purpose is to elicit a person's thinking or understand the development of thought. The driving questions that best fit this purpose are process questions related to how students solve the task or problem or how the task was interpreted by students. In contrast, the purpose of ECD is to design and deliver educational assessments that are fair, valid, and reliable. The driving questions focus more on whether there is alignment between what is collected as evidence of a student's competence and the stated goal of the assessment or whether valid inferences can be made about what students know, can do, or have accomplished based on the assessment design.

Design Process	Purpose	Driving Questions
Cognitive Labs	To elucidate thinking processes	How do students solve the task or problem? How do students interpret task or problem, or specific words or phrases in the question or task? What types of information or strategies are used/retrieved to answer the question or solve the problem?
Evidence-Centered Design	To design and deliver educational assessments that are fair, valid, and reliable	Is the evidence of comptence consistent with the assessment goal? What valid inferences can be made about what students know, can do, or have accomplished?
Iterative Design	To address design problems that are ambiguous with multiple solutions that are insufficiently solved by linear problem solving methods	What is most functional and simplest solution? What mechanisms drive X? How are solutions derived?
Problem-Based Learning	To solve complex and authentic problems that help develop content knowledge as well as problem solving, reasoning, communication, and self-assessment skills	What are possible solutions? How do practitioners of a discipline think about and solve problems within their field?

Figure 2. Design processes' purpose and driving questions.

Iterative design and PBL have similar purposes—to solve ambiguous or ill-structured problems with multiple solutions within an authentic context. The driving questions for both processes center on what gets produced to solve the problem. However, similar to cognitive labs, process questions are also appropriate. For example, if one is interested in knowing how decisions are made to arrive at a design solution, implementing the iterative design process would be well served.

Conclusion and Implications for the UDL Innovation Studio

What does this all mean for how the Studio plans to learn *with* and *from* individuals at Stanford, and beyond? One important consideration is at the UDL Innovation Studio faculty and students become partners in understanding how to design for all individuals. Another key contribution to society is that notions of diversity expand to include the normal but overlooked variations in cognition, emotion, and engagement. This is accomplished by engaging participants with specific design processes that incorporate human variability in the learning environment or product. For example, if the purpose is to understand how students experience a newly developed tool such as a reading app or medical device, then cognitive labs would be useful for ascertaining how students understand and engage with the tool and how best to apply UDL to design for the margins. However, if the purpose is to design a course assessment with teaching faculty that is fair and valid for all students, then the evidence-centered design process should be employed. The ECD process will help to ensure that what is collected as evidence of student competence within a domain is consistent with the assessment's goal and aligned with instruction. Engaging in this process will increase the likelihood that the inferences made about what students know, can do, or have accomplished are valid. In addition, the ECD process provides avenues for infusing UDL practices (i.e., providing multiple means of representations, of engagement, and of action and expression). For instance, within the conceptual assessment framework layer, the designer must specify the task model, which describes the environment in which students say, do, or make something to provide evidence of the claim. Additionally, the designer specifies the forms and key features of directives and stimulus materials and the presentation environment. Thus, designers (e.g., university faculty) could infuse UDL principles into the assessment such as language supports (e.g., including a technical glossary, hyperlinks/footnotes to definitions, illustrations) or engagement features (e.g., using real-world problems or contexts) to increase access to learning for all students.

Alternatively, if the purpose is to design UDL aligned instructional strategies and tools, then the iterative design process may be chosen to guide the work with students and faculty. As an example, the Studio may present a design challenge to students to develop a time management app for mobile devices. Students would work collaboratively to define the challenge, brainstorm ideas, sketch their ideas, create a prototype, and then test out their chosen solution and then iterate their solutions based on what they learn through the design process and soliciting feedback from end users (e.g., other students).

The work of the UDL Innovation Studio strives to help faculty prepare all students in the higher education community by designing learning environments that meet the needs of all learners. By working with students, the Studio is preparing thought leaders who can take UDL into the workforce with the understanding that society is made up of individuals who have multiple ways of understanding, engaging, and expressing actions, knowledge and skills. It is our hope that through this experience our workforce will begin to be characterized by people who understand that when we design with the broadest inclusion of individuals, everyone benefits. Using design processes in conjunction with the UDL Guidelines, barriers to the completion of higher education and contribution to society's workforce can be diminished. The process of engaging together into the application of the UDL Guidelines in itself raises awareness that individuals and learning are complexities that can be addressed so that everyone can experience meaningful lives and work . Thus, the UDL Innovation Studio will judiciously employ these research-based design processes in order to learn *with* and *from* students and faculty in order to allow all individuals to thrive in higher education and today's workforce.

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