Deep Conceptual Learning in Science and Mathematics: Perspectives of Teachers and Administrators

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Abstract

Research suggests deep conceptual learning (DCL) is distinctly different than surface learning. Deep conceptual learners tend to think, discuss, and question more, seeking to understand rather than only memorize. A commonality of the Common Core standards in mathematics and the Next Generation Science Standards is greater focus on depth by rejecting superficial survey curricula. These new approaches will require teacher professional development. The Interconnected Model of Teacher Professional Growth describes domains influencing teacher enactment of new initiatives. Information about teachers and administrators' Personal Domains and Domains of Practice were gathered and analyzed through an adaptive questionnaire on mathematics and science education at the middle school and high school levels. Questionnaire items included the extent to which DCL methods are put into practice, the perceived importance of DCL, the status of DCL in schools, and which instructional methods embody DCL. Survey results (N= 425) indicate respondents believe that DCL is very important for preparing students for careers and college. Both administrators and teachers generally believe that DCL is very important for mastering the new standards and there was strong agreement that (a) the learning environment influences student DCL behaviors and (b) DCLs are more likely to become lifelong learners.

Keywords: science education, mathematics education, deep conceptual learning, standards, teachers, administrators, professional development

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Introduction

Not since the reaction to the launching of *Sputnik* has U.S. science and mathematics education been at a greater potential inflection point. The Common Core mathematics standards and Next Generation Science Standards presage dramatic shifts in curricula for less breadth and more depth, rejecting superficial coverage for more profound learning (Common Core State Standards Initiative, 2010; NGSS Lead States, 2013; NRC, 2012; Rillero & Padgett, 2012). These standards seek to dislodge the prevailing curricula consisting of broad survey type courses characterized as one-inch deep and one-mile wide. Instead, fewer key concepts have been identified and students delve much deeper into these concepts, with the mantra "less is more."

With a strong majority of states adopting the Common Core State Standards (CCSS), there is potential to greatly impact children and schools (Common Core State Standards Initiative, 2016). While the newer Next Generation Science Standards (NGSS Lead States, 2013) currently has fewer implementing states (National Association for the State Boards of Education, 2014), these standards, however, are already influencing science education thought, curriculum, and practice (Hoffman & Turner, 2015). The prequel for NGSS is the book *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). According to the *Framework*, K-12 science education "emphasizes discrete facts with a focus on breadth over depth, and does not provide students with engaging opportunities to experience how science is actually done" (p. 1).

International comparisons indicating the U.S. lags in mathematics and science achievement informed CCSS and NGSS. U.S. educators tend to focus more on mathematical procedures with less concern if students understand the underlying concepts (Stigler & Hiebert, 1999; Stigler & Hiebert, 2009). "International studies have also shown that U.S. math and science textbooks cover comparatively more topics with less depth of coverage and development" (National Science Board, 2002, p 30).

Focusing on fewer key concepts is an opening to make learning deeper. The challenge, however, is to avoid making "less coverage" become a reduced amount of learning. To be sure, there have been many standards and curricula revisions in mathematics and science education. The focus on reducing the coverage of content and delving deeper, however, is a fundamental shift from previous reforms and past professional development efforts. Producing deeper learning may be a profound transformation for many U.S. teachers.

There is wide agreement that professional development should be a key part of implementing the new standards (Drits-Esser & Stark, 2015). New models of professional development have been developed that move past a correcting-teacher-deficit focus. One leading model is the Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002). In this empirically supported model, the Personal Domain is an important determinant of teacher action that is strongly influenced by the Domain of Practice and the Domain of Consequences. Conversely, the Personal Domain influences the Domain of Practice; beliefs and attitudes influence the enacted methods and content of teaching. Since deep conceptual learning (DCL) is a key aspect of new standards, it is important to develop insights into teacher and educational administrator views of DCL.

Literature Review

Deep Conceptual Learning

Research into deep learning emerged in the 1970s with Ference Marton and his group from the University of Göteberg examining college students' responses to academic articles presenting evidence supporting conclusions non-subject experts could understand (Marton, 1975; Marton & Säljö, 1976). Before reading, students were told they would be asked oral questions about the articles. Two distinct styles emerged. Some students tried to understand the articles and other tried to memorize specific things in the articles. Seeking to understand by (a) applying what they were reading to what they know and (b) by questioning and evaluating the content led to better recall and better understanding of the reading immediately and after several weeks.

A key aspect of Marton's work is that the same environment revealed two completely different styles of learning. Other research has supported characterizing DCL and surface learning as distinct approaches (Biggs, 1999; Chang & Chang, 2008; Hall, Ramsay, & Raven, 2004; Marton, Dall'Alba, & Beatty, 1993). Surface learning is marked by memorization, rote learning, and unquestioning acceptance of information. Deep Conceptual Learners (DCLs), however, join concepts, apply them to real life situations, or question conclusions (Lyke & Young, 2006). DCLs are more likely to read related materials, discuss, and reflect upon the content (Tait, 2009). Research suggests that these learners have better retention of information and apply it better than surface students do (Booth, Luckett, & Mladenovic, 1999; Ramsden, 1992). Most of the research on DCL versus surface learning is in higher education. As such, it is "one of the most significant conceptual frameworks for understanding teaching and learning in higher education" (Tormey, 2014, p. 2).

Deep Learning Environments. While people may have tendencies toward deep or superficial learning, the learning situation can affect the learning approach. Time pressures and cramming information to do well on exams leads to surface learning, as do assessments that focus only on superficial details (Elby, 1999). Learning environments with rich resources, warm classroom cultures, appropriate workload, and well-sequenced curriculum can promote curiosity about a subject leading to DCL (Rodriguez & Cano, 2007; Trigwell & Prosser, 1991). The levels of student engagement, as influenced by curriculum and teachers, may be a critical factor in promoting DCL (Goldspink & Foster, 2013).

DCL and New Standards. The first sentence of the Common Core Mathematics Standards states:

> For over a decade, research studies of mathematics education in high-performing countries have pointed to the conclusion that the mathematics curriculum in the United States must become substantially more focused and coherent in order to improve mathematics achievement in this country. (Common Core State Standards Initiative, 2010, p. 3)

The intent of the new standards is not only to achieve more focused content but to ask learners to demonstrate deep conceptual understanding of core mathematics concepts by applying them to new situations (Common Core State Standards Initiative, 2010).

The *Framework* (NRC, 2012) of the Next Generation Science Standards also stresses deeper learning as it narrows the wide coverage of science and focuses on fewer concepts so learners can achieve depth of understanding. DCL is an intended outcome for new science and mathematics standards that influences both the content taught and methods used. Teachers and administrators will need new approaches to help in this paradigm shift in teaching and learning (Hirsh, 2012).

Professional Development Models

The basic unit of educational change is the individual classroom that is directly influenced by the teacher and indirectly influenced by administrators (McLaughlin & Marsh, 1978). Professional development processes that meet the concerns and needs of teachers and school administrators are a key component of educational change (Hall & Loucks, 1978; Weatherley & Lipsky, 1977). Thus, almost every modern educational improvement initiative is accompanied by professional development efforts (Guskey, 2002). Yet, individual classrooms are physically separated by others and this can isolate teachers from others and from enacting calls to change (Lortie, 1975).

The history of teacher professional development began shortly after the establishment of preservice teacher education—inservice teachers often needed the knowledge and skills that were being taught to preservice teachers (Neil, 1986). As methods of professional development were scrutinized two concerns rose to the surface: one-shot professional development and the deficit approach. The one-day or one-session professional development, with little continuity or coherence, had little effect on how teachers taught (Fullan & Stiegelbauer, 1991; Johnson, 1989). This led to more sustained initiatives, including modern methods such as lesson study and professional learning communities (Cheng & Lee, 2011/2012; Lieberman, 2009). The deficit approach, where professional development seeks to fix something that is not working well, frequently focuses on big changes rather than engineering tweaks. As a model it has also not been shown to be effective (Guskey, 1986; Wood & Thompson, 1993).

Increasingly, the shift on the focus of professional development has been from programs designed to change teachers to a focus on facilitating professional learning (Clarke, Hollingsworth, & Gorur, 2013; Guskey, 1986; Hall & Loucks, 1978). A lineage of professional development models for teacher education led to the development of the Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002). This model, presented in Figure 1, accounts for four domains promoting understanding and facilitation of teacher professional growth. The Personal Domain is the knowledge, beliefs, and attitudes of the educators. The External Domain includes exterior to the teacher sources of information or stimuli. The Domain of Practice is the actions that educators take in their professional work. The Domain of Consequences is the salient outcomes from teaching enactments informed by reflection (Clarke & Hollingsworth, 2002).

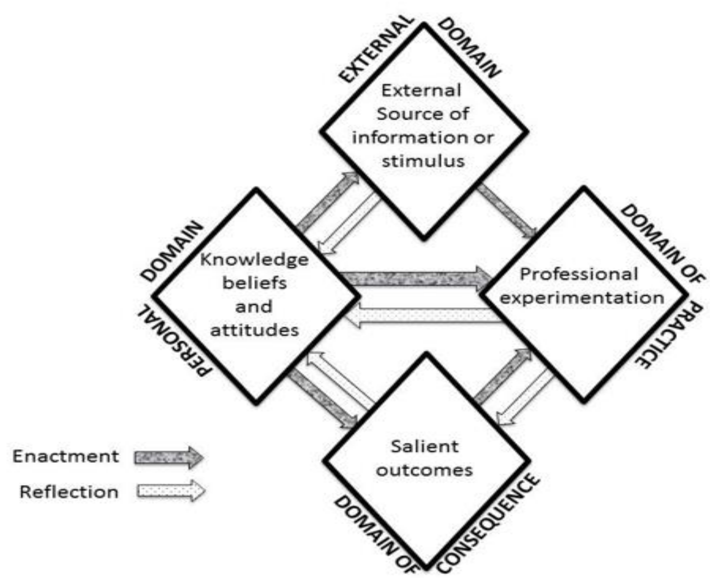

Figure 1. A graphical depiction of the Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth 2002)

An example of the External Domain is a state adopting new standards. This is an immediate influence on districts, schools, and teachers. The district response to the standards and the administration's response to the district become elements in the teacher's External Domain. The Personal Domain of the teacher evaluates new initiatives. The initial views of new methods and standards are shaped by teachers' Domain of Practice and the resulting Domain of Consequences (Clarke & Hollingsworth, 2002).

What educators have experienced, know, and believe are of great importance for the implementation of new standards with new approaches to teaching and learning. The Personal Domain of educators regarding a proposed shift in content and instruction is a key driver of enacted practices. In a similar way to good science teachers knowing the interests, abilities, and alternate conceptions of their students; effective professional development in DCL can be informed by greater understanding of educators' Personal Domains regarding this type of learning. This exploratory study sought to determine teacher and administrators views on methods, benefits and challenges of DCL.

Methods

In this exploratory study, an adaptive questionnaire was developed to gain understandings of the perspectives of teachers and administrators regarding DCL in mathematics and science education at the middle school and high school levels. The questionnaire included background questions and determinant items for the extent DCL is practiced, perceived importance of DCL, and which instructional methods embody it. The adaptive questionnaire method with variability in questions based on individual responses sought deeper information (Chou, Chang, & Jiang, 2000). Teachers that responded affirmatively that they used DCL methods in their teaching, for example, were then prompted to list methods used. Questions with open responses were grouped into emergent categories. The survey was developed and administered electronically on SurveyMonkey®.

As an exploratory study, the survey was designed to be broad and much of the data were qualitative (Stebbins, 2001). To keep the survey broad but not too time consuming by participants, there was no attempt to have multiple items measure a single variable. For these reasons, reliability was not determined. Translation validity (Drost, 2011) was determined by a panel with terminal degrees in science education, mathematics education, and psychology.

Email messages were sent to U.S. middle school and high school educators with roles in mathematics or science inviting their participation and letting them know if they respond to the email they would be entered into a lottery with the possibility of winning a raffle for computer tablets and gift cards. The questionnaire was open for a fortnight. A total of 502 people responded to the email and, of these, 481 individuals answered survey questions. Respondents were removed if the majority of questions were not answered or if their role didn't cover mathematics or science at the middle school or high school levels, leaving a total sample size of 425 with an overall completion rate of 84.6%. Not all respondents completed all sections resulting in a slight variability in reported sample sizes.

Results

Background of Teachers and Administrators

The two main categories of respondents were teachers (77.1%) and administrators (18.9%), with 4% percent in the "other" category consisting mostly of curriculum/area specialists and coaches. The teachers reported teaching the following subjects: middle school mathematics (18.4%); middle school science (20.7%); and high school mathematics (24.5%), biology (20.1%), chemistry (20.1%), and physics (14.9%). Teachers could list more than one subject making the total percentage exceed 100%. The mean size of the teachers' schools is 1,032 students. Experienced teachers responded to the questionnaire; 81% of the sample had seven or more years of experience.

For administrators, 45.7% have district-level positions and 51.9% had school positions. The average size of their districts is 8,176 students. The job titles listed were coded into categories. Most were either principals or heads of schools (48.1%), administrators of curriculum and/or instruction (28.4%), or assistant superintendents (8.6%).

Implementation of DCL Methods

Approximately 87% of the teachers indicated they were implementing DCL methods in their schools and 78% indicated that they used technology to support DCL (Table 1). Yet only about half (55.6%) responded affirmatively about possessing instructional materials that support DCL. Only 37% of the teachers indicated they had participated in professional development on DCL. Administrators shared a similar view on instructional materials, with 51.3% indicating that their materials supported DCL. A greater percentage of administrators (43.6%) had received professional development on DCL.

Table 1
Implementation of Deep Conceptual Learning (Yes/No Questions)

	Yes	
	Frequency	Percent
Teacher		
Do you implement deep conceptual learning methods in your school?	277	86.8%
Do your current instructional materials support deep conceptual learning?	179	55.6%
Do you use technology to support deep conceptual learning?	253	78.8%
Have you ever had professional development in deep conceptual learning methods?	118	37.0%
Administrator		
Do you implement deep conceptual learning methods in your school?	59	76.6%
Do your current instructional materials support deep conceptual learning?	40	51.3%
Do you use technology to support deep conceptual learning?	50	64.1%
Have you ever had professional development in deep conceptual learning methods?	34	43.6%

For the adaptive prompt on professional development, 41% of the teachers reported receiving it through their school or district and 37% engaged in it through other experiences, with 22% receiving both categories. Professional development received outside of the school/district, included training as part of a degree program, conferences, and local professional development programs. Several respondents said the professional development received may not have been called DCL but that the instruction covered related topics. For administrators, a total of 71% received professional development on DCL through their school or district, 33% outside of the district, and 4% engaged in both.

Perceived Importance of Deep Conceptual Learning

Teachers and administrators generally indicated that DCL was very important (Table 2). On a six-point Likert scale, where six is extremely important, five is very important, and four is important, the means for teachers and administrators were between five and six for the following items: (a) in middle and/or high school education and (b) for preparing students for college and careers. The teacher mean (4.92) and administrator mean (5.37) were slightly lower for the importance of DCL in helping students master new standards.

Table 2

How important is Deep Conceptual Learning?

	Mean	SD
Teacher		
How important is deep conceptual learning in middle/high school education?	5.19	.89
Do you think deep conceptual learning is important to prepare students for college and careers?	5.42	.78
Do you think deep conceptual learning is important to help students master the Common Core State Standards?	4.92	1.06
Administrator		
How important is deep conceptual learning in middle/high school education?	5.55	.61
Do you think deep conceptual learning is important to prepare students for college and careers?	5.61	.58
Do you think deep conceptual learning is important to help students master the Common Core State Standards?	5.37	.83

Note. Teachers $n = 343$ to 342 and administrators $n = 82$. 6 = Extremely Important, 5 = Very Important, 4 = Important 3 = Somewhat, 2 = A Little, and 1 = Not at All.

Benefits Reported by Teachers. The most common response cluster for the open-ended question about benefits (see Table 3) was students becoming more effective thinkers in a variety of contexts. Thirty percent of the respondents mentioned this benefit. The following are specific teacher responses in this category:

- “They develop thinking skills that go beyond looking answers up out of the book. Those thinking skills can be transferred to all aspects of their lives.”
- “They're not limited by their knowledge in one particular area— they can make connections between disciplines, and they know how to find the information they need to succeed, no matter what they're trying to accomplish.”

Table 3
Teacher Reported Benefits of Producing Deep Conceptual Learners

	n	%
More effective thinkers and decision makers in a variety of areas	88	30.0%
Will be more prepared/successful in school, college and job life	74	25.2%
Better problem solvers	74	25.2%
Make connections/apply knowledge	58	19.7%
Lifelong learners	44	15.0%
Independent/self-directed thinkers	43	14.6%
More engaged/motivated/confident students	34	11.6%
Knowledge is retained longer	29	9.9%
Critical thinkers	16	5.4%
Creative/flexible thinkers	16	5.4%

Note. Teacher n = 294; Categories coded less than 16 times are not recorded.

The second and third categories received an equal number of responses. Being (a) a better problem solver and (b) prepared/successful in school, college, and life was mentioned in 25.2% of the responses. The following are teacher comments for problem solving:

- "These students will be better at analyzing information by knowing that there may be more to a problem or situation they encounter."
- "They are better problem-solvers; they understand how to learn in a variety of settings; they can answer questions of types they haven't seen as well as types they have seen."
- "Better problem solvers, stronger critical independent thinking, more informed to make better decisions."

Teachers explained that developing better thinking skills and understanding concepts deeply would transfer to a college and/or a job setting, making learners more likely to succeed after graduation. These responses frequently included that the learner would be a better community member and contributor to society.

- "These students can make connections to real life and bring that knowledge to career and college preparation. These students enjoy education more and have a much higher chance of success in both college and career."
- "These skills assist students in all areas of life, help them become better prepared for college, make the student much better participants in our society and democracy, prepare students for leadership, give students a competitive advantage over those who don't have the skills, help the student become a lifelong learner and learn in any environment and improve test performance."

Benefits Reported by Administrators. The same categories were used to code responses from administrators but different relative frequencies emerged. The most frequently mentioned category was that students would be more prepared or successful in school, in college, and in a job (37.1%). The second most frequently used category was that students would be better problem solvers (22.9%) and the third was that students would be more effective thinkers and decision makers in a variety of areas (17.1%).

- "They are capable of thinking and performing at a higher level, do better in college and real life."
- "Higher wage, higher competitive jobs, college and career readiness, better workforce, creative/inventors"
- "Higher achievement, life-long learners, motivated students, successful schools"

The Practice of Deep Conceptual Learning

A section of Likert items focused on levels of agreement related to the Domain of Practice and Domain of Consequences of DCL (Table 4). Teachers and administrators tended to strongly agree that DCLs become lifelong learners (on a 5 point scale Teachers 4.47 and Administrators 4.56), the environment influences whether students become DCLs (4.43 and 4.56), and an interactive learning environment supports DCL more than textbooks (4.36 and 4.53). Educational technology and modes of assessment were also seen as important in promoting DCL (both were rated just below 4.0 or the "Agree" anchor by teachers and above the anchor by administrators). Also rated near the "Agree" anchor, teachers and administrators indicated that the concepts to be learned influenced whether students become DCLs. The items stating, "It is clear that my…" (a) district and (b) state "have an interest in promoting DCL" both had lower ratings of agreement, but remained above the "Neutral" anchor. Rated with the lowest level of agreement by teachers and administrators were the items on (a) individual tendencies influencing the type of learner a student becomes and (b) more students are becoming deeper conceptual learners every year.

Table 4
Deep Conceptual Learning in Practice

	Teachers		Administrators	
	Mean	SD	Mean	SD
The tendency to be a deep conceptual learner versus a surface learner is very much an individual tendency.	3.16	1.00	2.67	.98
Deep conceptual learners are more likely to become life-long learners than surface learners are.	4.47	.75	4.56	.64
Every year, it seems like students are becoming deeper conceptual learners.	2.38	.90	2.86	.85
The learning environment has a profound influence on whether students become deep conceptual learners.	4.43	.66	4.56	.55
It is clear that my district has an interest in promoting deep conceptual learning in science and mathematics.	3.49	1.00	3.85	.85
It is clear that my state has an interest in promoting deep conceptual learning in science and mathematics.	3.24	1.08	3.60	1.04
The concepts to be learned deeply influences if	3.82	.88	3.97	.77

students become deep conceptual learners.				
I believe that students gain deep conceptual learning in an interactive learning environment more than reading about concepts in a textbook.	4.36	.75	4.53	.66
Educational technology gives me the ability to enhance deep conceptual learning.	3.93	.77	4.10	.66
The modes of assessment deeply influence if students become deep conceptual learners.	3.92	.89	4.25	.71

Note. N for teachers=314 and administrators=78; coding: a=Strongly Agree, 4=Agree, 3=Neutral, 2=Disagree, and 1=Strongly Disagree.

The responses to items related to perceived enactment of DCL methods (Table 5) suggest teachers and administrators overwhelmingly did not feel that U.S. schools are putting enough emphasis on DCL. Both groups also felt the need for better professional development, materials, and technology.

Table 5
Conditions for Deep Conceptual Learning

	Yes	
	Frequency	Percent
Teacher		
Do you think U.S. schools are putting enough emphasis on deep conceptual learning?	36	11.1%
Do you wish you had more opportunities for professional development in deep conceptual learning methods?	295	91.9%
Do you want better access to materials/programs that support deep conceptual learning?	306	95.0%
Would you like to have access to technology programs that support deep conceptual learning?	306	95.0%
Administrator		
Do you think U.S. schools are putting enough emphasis on deep conceptual learning?	4	5.1%
Do you wish you had more opportunities for professional development in deep conceptual learning methods?	74	94.9%
Do you want better access to materials/programs that support deep conceptual learning?	76	97.4%
Would you like to have access to technology programs that support deep conceptual learning?	74	96.1%

Deep Conceptual Learning Methods

If respondents answered affirmatively to the item asking if they implement DCL methods in their school (Table 1), the adaptive prompt asked them to list methods used. The responses were coded into categories. The top five most frequently used methods by teachers to engage students in DCL were experiments or lab activities, real world applications of content, discussions and debates, the use of technology, and inquiry-based methods. The top five methods listed by administrators also included inquiry-based methods and the use of technology. However, in contrast to teachers, the top five also included project-based learning, assessment strategies or questioning techniques, and connecting concepts (e.g. providing connections to previously learned content).

Table 6 presents the teachers' Likert-item responses for methods of promoting DCL listed from highest rating to lowest ratings. There are similarities between teachers and administrators, with both highly rating applications of concepts to everyday life, problem-based learning, discovery learning, multiple representations, and using analogies to tie new concepts to previously learned concepts. There was also agreement between teachers and administrators on the methods *least* likely to yield DCL. The three lowest rated methods were the use of PowerPoint presentations, classroom lectures, and readings from textbooks.

Table 6
Deep Conceptual Learning Methods (Teachers)

Instructional Method	Mean	SD
Applications of concepts to everyday life	4.32	.74
Problem based learning	4.26	.77
Discovery learning	4.21	.85
Multiple representations	4.08	.79
Using analogies to tie new concepts into already learned concepts	4.05	.75
Student research	3.98	.87
Student-led discussions	3.97	.82
Projects	3.92	.84
Immediate feedback	3.91	.87
Trial and error learning	3.85	.92
Virtual manipulatives	3.73	.86
Readings from recent science news	3.36	.88
Self-paced learning using technology	3.32	.92
Teacher-led discussions	3.32	.86
PowerPoint presentations	2.86	.95
Classroom lectures	2.71	.88
Readings from textbooks	2.61	.82

Note. N=311-315 with scale of 5=To a great extent, 4=To a considerable extent, 3=To some extent, 2=To a small extent, and 1=Not at all.

Challenges

Teacher Challenges. Teachers and administrators were prompted to describe challenges of enacting DCL and these responses were categorized by emergent themes. Teachers reported time as the most challenging factor in their school (33%; see Table 7). Time included both teaching time and preparation time. Many teachers described the challenge of a broad curriculum that did not delve deeply into concepts. This was often associated with high stakes testing for the curricula requiring instructional time for test preparation. In addition, teachers indicated inadequate preparation and planning time to develop lessons and strategies to support DCL. Below are some quotes taken from the responses.

- "State & district pressure to get through all the learning targets by May testing time. Time to find or create activities that will promote conceptual learning (our current textbooks do not do this)."
- "Timeline of 'covering' so many chapters to prepare students for state tests. Textbooks support rote learning. More senior teachers do not support project-based or inquiry-based learning. New teachers have to almost do these projects in secret."

Table 7
Teacher Reported Challenges to DCL

	N	%
Time (student learning, teacher planning)	96	33.0%
Student behavior/attitude towards learning	67	23.0%
Standardized testing/GPA	65	22.3%
Changing/implementing teaching methods and curriculum to support DCL	62	21.3%
Lack of support material/resources	54	18.6%
Getting staff on board	36	12.4%
Lack of prerequisite knowledge (e.g., content, reading, learning ability)	35	12.0%
Funding	28	9.6%
Lack of technology	27	9.2%
Administration/State challenges	23	7.9%
Parental Support	22	7.6%
Professional Development	20	6.9%

Note: Categories coded less than 20 times are not reported.

The second most frequent category was student attitude and/or behavior (23%). Teachers explained that students were accustomed to surface learning and would rather memorize than take time to understand concepts deeply. Several teachers said that students in urban schools with low socioeconomic status were difficult to engage in DCL. On the other hand, several other teachers said that students who had access to more resources were unmotivated as they expected everything to be given to them with little need for effort on their end.

- "Surface learning has been ingrained within students for the 10 years before they come to my class. This makes it difficult for student to learn to think deeply and/or conceptualize. I often hear students saying 'Just tell me the formula so I can use it and move on' and this has worked for them in the past."
- "The students that we have. Many are of low income and don't care for school. They are only here because they have to be."
- "Students are using their phones for personal texting and gaming. Their attention spans have decreased. They believe that the material should be handed to them. They do not want to work to learn. I don't mean more worksheets; I mean they don't want to have to think. If it is challenging, many students won't attempt."

The third greatest challenge is standardized testing (22.3%). Teachers explained that standardized testing is not aligned with DCL.

- "Teaching to the test and racing to cover too much material to allow students to do anything other than memorize and regurgitate, lack of time and focus to pick fewer topics to change from teacher as giver of knowledge to students as discovers, researchers, and problem solvers."
- "The emphasis on standardized testing makes some of the deep conceptual learning 'impractical' or not data-driven, as much as explicit direct instruction."

Another challenge implementing DCL is the curricula and teaching methods in use (21.3%). It was stated that many of the instructional materials that influence both curriculum and methods do not promote DCL, making lack of support materials a frequent issue (18.6%). Students entering class with a lack of prerequisite knowledge, poor reading ability, and/or the inability to learn conceptually was another depicted challenge (12%) that can be complicated by learners at different levels.

- "There are limited resources that exist to help teachers understand how to teach in a way that supports deep conceptual learning. Teachers may not understand how to tie a lesson to a real world situation so they turn to the book too often."
- "The math curriculum keeps changing but there is very little support or resources developed by NCDPI to help teachers. My school hasn't bought new precal or calculus textbooks in 8+years."
- "Students need to come to a course prepared for that course. I have students enrolled in Geometry that do not know Algebra I. They have taken and passed Algebra I but do not truly know how to solve equations. A child cannot reach a deeper understanding if they do not even have a basic understanding of the fundamental principles we are trying to build on. That is the biggest problem."
- "A big struggle is figuring out how to manipulate your classroom so both your high and low level learners are practicing deep conceptual learning, but at their specified level. Also, having resources to help support deep conceptual learning."

Administrator Challenges. Administrators shared some challenges that were similar to teacher challenges. The biggest challenge mentioned was Professional Development (32.9%). Administrators explained that teachers need training in new teaching methods, especially seasoned teachers. Staff and funding cuts make professional development a bigger challenge. The second largest challenge listed was teacher buy-in to instructional change (30.0%). This can be a challenge for a group of teachers with different instructional values and views, and is influenced by how they were taught to teach and how they respond to testing and accountability systems. Administrators agreed with teachers that time was a big challenge (21.4%). This includes teacher and student instructional time, as well as a lack of time for professional development.

- "Teachers are stuck in the old methods/ways of teaching. They don't understand how to teach to support deep conceptual learning."
- "Need deep thinking teachers, time to develop lessons/projects that support critical thinking, PD that addresses these issues, loss of time to state standardized prep, students come with multiple academic gaps from prior academic experiences"
- "Professional development for all staff and a consistent implementation of this process. This deep conceptual learning needs to be the climate and environment that is prevalent to all students."

Discussion

Domains of Practice, Personal and Consequences

While DCL is not a dominant practice in schools there are experiences with it that have informed teacher and administrator views. Among the teacher respondents, 86.8% had implemented DCL methods and 76.6% of administrators reported it in their schools. Teachers described a range of methods that promote DCL with the most highly rated being applications to everyday life, problem-based learning, and discovery learning and the least highly rated being PowerPoint presentations, lectures, and reading from textbooks. Goldspink and Foster's (2013) observations that there is a relationship between DCL and levels of student engagement is consistent with teacher rankings. More teacher centered instruction with less social interaction was perceived as the weakest way to promote DCL.

Implementing methods or observing DCL had a potential influence on the respondents Personal Domains and Domains of Consequences. The respondents showed a strong understanding of DCL and expressed many positive aspects. They tended to view it as important for college and careers, and they saw benefits for promoting thinking, problem solving, and connections to other disciplines (Figure 2).

Teachers and administrators shared similar views. Administrators, however, placed a larger emphasis on the challenge of teacher buy in when it comes to implementing DCL approaches. The teachers saw time, curricula, and standardized tests as barriers to implementing DCL. Teachers who see the benefits of DCL may embrace new standards-inspired curricula, materials, and correlated exams that have a greater focus on deeper learning.

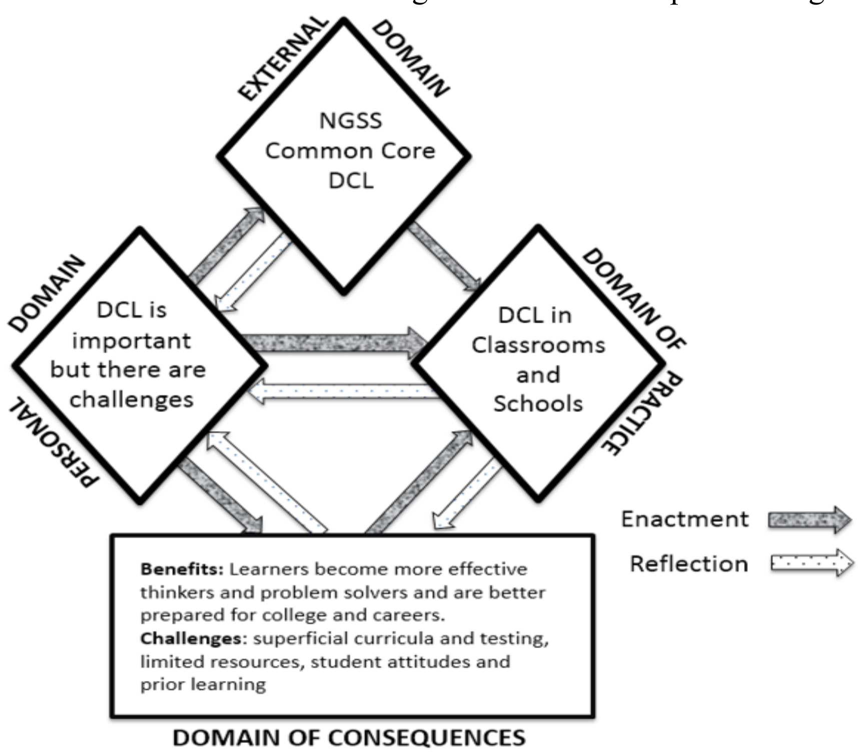

Figure 2. Domains of the Interconnected Model of Teacher Professional Growth related to DCL.

The Challenges

The teacher and administrator means for the importance of DCL to master new standards was about 5 (very important) on a six point scale. It is encouraging that the group sees the connection between DCL and the new standards and this might be an important link to further develop in professional development programs. Teachers who lament superficial curriculum should be enthusiastic implementers of new science and mathematics standards.

The item on "individual tendencies influencing the type of learner a student becomes" had a lower rating by teachers. While previous research does show there are individual tendencies towards being one type of learner, other research also suggests the learning situation does affect the learning approach. Previous research on teacher self-efficacy suggests that teachers who think they can influence a learning situation have greater efficacy (Gibson & Dembo, 1984). Thus attributing the learning environment to DCL may indicate that teachers believe they have can influence this area. Research does suggest that teacher strategies related to the structures and processes in the learning environment influence whether DCL or surface learning will occur (Dunleavey & Milton, 2008; Garrison, Cleveland-Innes, & Fung, 2004). The Teacher and administrator respondents generally felt that there was not enough DCL in their schools and they overwhelming wanted more professional development in this area.

Some of the educators expressed concern about the students in their schools and DCL methods, which were seen as a departure from the norm. Student attitudes of wanting teachers to just tell them what they need to know were thought to be a possible hindrance. Poor previous preparation in the content area was also seen by some teachers as a potential barrier. Boulton-Lewis, Marton, Lewis, and Wilss (2004) found that indigenous Australians with difficult living conditions who strived to be DCL failed "because most of them had a limited educational background in terms of academic language and knowledge and partly because they were dealing superficially with the texts" (p. 107). Strategies that help students to overcome barriers so they can have entre into academic DCL need to be developed and shared with educators.

Limitations

This was an exploratory study that used a sample of convenience with the limitation that this sample may not be representative of the larger population. Care should therefore be taken in generalizing the results of this study beyond these respondents.

Conclusions

The teachers and administrators participating in this survey generally believe that DCL is very important in middle and high school and for preparing students for careers and college. They generally believe that DCL is very important for mastering new standards and there was strong agreement that (a) the learning environment affects if students become DCLs and (b) DCLs are more likely to become lifelong learners. The average response, however, for how well U.S. schools are implementing DCL strategies fell between "to some extent" and "to a small extent." Both groups rated their own schools slightly higher than U.S. schools in general but they also believed that strategies such as memorization and rote learning were stressed more than DCL strategies in their schools. Indeed, a little more than half of the teachers and administrators did not believe that current instructional practices support DCL. Only 37% of the teachers reported having professional development in DCL and over 90% of teachers and administrators expressed the desire for more professional development. Over 95% of the teachers and administrators indicated they want access to materials and technology programs that support DCL. Challenges to enacting DCL include time pressures, curricula that are too broad, standardized tests, student attitudes, and lack of resources.

Strong positive attitudes toward the importance and benefits of DCL bode well for profound changes in mathematics and science education. New standards offer solutions for problems such as curricula being too broad and standardized exams focusing on surface knowledge. Professional development programs to help teachers and administrators recognize effective tools and methods for DCL need to be delivered. With these in place, it will be possible to turn disinterested surface students into learners seeking to connect concepts and apply learning to their lives.

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