DCMP Curriculum Design Standards

Annotated Bibliography

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This bibliography summarizes selected research that informed each of the DCMP's six [curriculum design standards](#).

Standard 1: A Student-Centered Culture of Learning

Chi, M. T., & Wylie, R. (2014). The ICAP framework: Linking cognitive engagement to active learning outcomes. *Educational Psychologist, 49*(4), 219–243.

> The authors proposed the ICAP (*Interactive*, *Constructive*, *Active*, and *Passive*) framework to characterize students' cognitive engagement in the classroom. They asserted that as students move through a spectrum of increased cognitive engagement—from passive to active to constructive to interactive—their learning will increase. The empirical evidence validated this hypothesis.
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> *This paper defines the DCMP's interpretation of a student-centered culture of learning and justifies the emphasis on constructive and interactive engagement.*

Laursen, S. L., & Rasmussen, C. (2019). I on the prize: Inquiry approaches in undergraduate mathematics. *International Journal of Research in Undergraduate Mathematics Education, 5*, 129–146.

> The authors established a "four-pillar" model for learning with inquiry. Two pillars addressed student learning: (1) student engagement in meaningful mathematics, and (2) student collaboration for sense making. The other two pillars addressed instructor action: (3) instructor inquiry into student thinking, and (4) equitable instructional practice to include all in rigorous mathematical learning and mathematical identity building.
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> *This paper defines an evidence-supported framework for student-centered instruction. The student-focused pillars match the DCMP principles of constructive engagement (student engagement in meaningful mathematics) and interactive engagement (student collaboration for sense making). In addition, the instructor actions align with what is expected in the teaching notes for the DCMP course materials. In particular, the attention to equity in the fourth pillar supports the thread of diversity, equity, and inclusion that weaves across all of the design standards.*

Hodges, L. C. (2020). Student engagement in active learning classes. In J. J. Mintzes & E. M. Walter (Eds.), *Active learning in college science: The case for evidence-based practice* (pp. 27–41). Springer.

The author noted that generic "active learning" in STEM classes is insufficient to improve learning. The active learning approach must be calibrated and supported by instructional guidance. This approach included question and activity design, discussion prompts, incentives for participation, and group dynamics. The author described what the ICAP framework looks like in the classroom and stressed how, with proper instructor guidance, moving toward constructive and interactive engagement evokes deeper thinking and improves learning.

This chapter supports the use of the ICAP framework in the design standard. In particular, it supports the emphasis on constructive and interactive engagement and the use of carefully crafted instructor notes with the course materials.

Khasawneh, E., Hodge-Zickerman, A., York, C. S., Smith, T. J., & Mayall, H. (2023). Examining the effect of inquiry-based learning versus traditional lecture-based learning on students' achievement in college algebra. *International Electronic Journal of Mathematics Education, 18*(1), em0724.

This study compared student achievement in a college algebra course with inquiry pedagogy, with the same in a college algebra course with traditional lecture. The authors argued that inquiry pedagogy not only improved student learning, but it also was more effective in preparing students for the 21st-century economy.

The authors defined inquiry pedagogy based on Laursen and Rasmussen's (2019) four pillars, specifically as "a student-centered pedagogy that focuses on student engagement in sequenced and scaffolded learning." In Khasawneh et al.'s study, the inquiry course administered problems designed to deeply engage student thinking with meaningful mathematical tasks, identify issues and underlying principles, and collaborate to process the mathematical ideas. Using a pre/posttest on a validated 25-item, multiple-choice college algebra content test, and controlling for pretest scores, the authors found that students in the inquiry course (23 subjects) scored significantly higher on the posttest than those in the lecture course (18 subjects).

This study supports the design standard and specifically endorses the emphasis on constructive and interactive engagement, which aligns with the authors' implementation of inquiry.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo E.N., Behling, S., Chambwe, N., et al. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences, 117*(12), 6476–6483.

The authors argued that narrowing achievement gaps in STEM is necessary to reduce income inequities. They performed a meta-analysis comparing student achievement, disaggregated by race and ethnicity or socioeconomic status, between active learning and traditional classes. The authors obtained two different datasets. One dataset included 9,238 individual student records from 51 classrooms in 15 different studies; the data came from identical or equivalent exam scores. The second dataset included 44,606 individual students from 174 classrooms in 26 different studies; the data came from pass rates.

In both datasets, the authors saw improvement in performance among underrepresented students in active learning classes. Regarding exam scores, they found a 33% reduction in achievement gaps; in terms of passing rates, the achievement gaps were reduced by 45%. A closer look at the data showed that the most significant factor in the success of active learning in reducing achievement gaps is the percentage of time spent on active learning. The larger this percentage, the more significant the improvement in narrowing achievement gaps.

This study, while vague in its definition of active learning, supports the design standard as a critical attribute of classrooms that attend to diversity, equity, and inclusion.

Standard 2: Supporting Students in Developing as Learners

Hurrell, D. (2021). Conceptual knowledge or procedural knowledge or conceptual knowledge and procedural knowledge: Why the conjunction is important to teachers. *Australian Journal of Teacher Education (Online), 46*(2), 57–71.

The author reviewed the literature on the relationship between conceptual mathematical knowledge and procedural knowledge. Conceptual knowledge is relational knowledge that can be applied to nonroutine problems. In contrast, procedural knowledge is the capacity to follow steps in a sequence to solve a problem. The author found that the relationship between the two forms of mathematical knowledge is bidirectional—each mode of knowledge supports the other. While the evidence in the literature tended to emphasize a conceptual approach prior to a procedural approach, some evidence showed that the benefits of such a sequence may be outweighed by student resistance.

This paper supports the emphasis in the design standard on nonroutine problems with support for procedural knowledge, where the instructional notes and choices of context in the curriculum raise students' curiosity to reduce resistance.

Czocher, J. A., Melhuish, K., & Kandasamy, S. S. (2020). Building mathematics self-efficacy of STEM undergraduates through mathematical modelling. *International Journal of Mathematical Education in Science and Technology, 51*(6), 807–834.

The authors argued that mathematical modeling classroom activities can potentially support student gains in self-efficacy. They proposed a theoretical framework and tested it empirically by examining a mathematical modeling competition. They found that mathematical modeling can lead to gains in student self-efficacy.

This paper supports the design standard by specifically suggesting that nonroutine problems encountered in mathematical modeling can promote student self-efficacy. Many lessons in the DCMP curriculum can be described as incorporating mathematical modeling as a form of nonroutine mathematical problem solving.

Morris, P., Agbonlahor, O., Winters, R., & Donelson, B. (2023). Self-efficacy curriculum and peer leader support in gateway college mathematics. *Learning Environments Research, 26*(1), 219–240.

The authors studied an intervention based on self-efficacy theory in college algebra and precalculus at a university. There were 325 students in sections where the interventions occurred, and 2,727 students in sections where there were no interventions. The study found that college algebra students were three times as likely to pass if they were in the section with interventions. In contrast, there was no statistically significant difference in pass rates for precalculus students. In both courses, final exam scores were significantly higher for students who were in sections with the interventions.

This study supports the design standard's emphasis on self-efficacy. It ties improvement in self-efficacy to improved academic outcomes.

Skinner, E. A., Graham, J. P., Brule, H., Rickert, N., & Kindermann, T. A. (2020). "I get knocked down but I get up again": Integrative frameworks for studying the development of motivational resilience in school. *International Journal of Behavioral Development, 44*(4), 290–300.

This paper examined the notion of students' "motivational resilience," which was defined as patterns of action that allow students to deal constructively with, overcome, recover, and learn from encounters with academic obstacles and failures. The authors identified several constituent components of motivational resilience:

1. Academic resilience — processes that allow students to succeed in school despite the presence of significant adversity or risk factors that typically lead to poor academic outcomes
2. Mastery, helplessness, and mindsets — one's orientation on whether they can master their environment
3. Engagement and re-engagement — ongoing, active, attentive, energized involvement and persistence in learning activities
4. Academic coping — the ways in which students deal with the challenges, obstacles, setbacks, and failures encountered daily in their academic work
5. Self-regulated learning — self-generated thoughts, feelings, and actions that are planned and cyclically adapted to the attainment of personal goals
6. Emotional regulation — processes by which individuals modulate their emotional experience and expression
7. Adaptive help-seeking — referring to resources outside of oneself to find information or strategies that will assist in accomplishing a task or solving a problem
8. Buoyancy — the ability to deal with everyday academic setbacks and challenges
9. Grit — perseverance and passion for long-term goals
10. Academic tenacity — mindsets and skills that allow students to look beyond short-term concerns to longer term or higher order goals, and to withstand challenges and setbacks to persevere toward these goals
11. Academic perseverance — a tendency to complete school assignments in a timely and thorough manner to the best of one's ability despite distractions, obstacles, or level of challenge
12. Productive persistence — the tenacity and strategies to persist despite challenges

The authors unified these components into a complex model that described their interactions and pointed out the important role of social contexts in motivation.

This paper supports the design standard's emphasis on the role of struggle in learning and the intentional use of monitoring, evaluating, and reflecting on one's learning. The paper also supports the emphasis on a growth mindset.

Samuel, T. S., & Warner, J. (2021). "I can math!": Reducing math anxiety and increasing math self-efficacy using a mindfulness and growth mindset-based intervention in first-year students. *Community College Journal of Research and Practice, 45*(3), 205–222.

This study examined a daily intervention based on mindfulness and a growth mindset in a community college statistics course. Seventeen participants in the course received the intervention, and 15 participants did not. Based on a pre/posttest survey of math anxiety using a valid and reliable instrument, those who received the intervention had a statistically significant drop in math anxiety. There were significant differences from those who did not receive the intervention. In addition, those who received the intervention had a statistically significant improvement in their self-efficacy.

Despite the small sample sizes in this study, findings showed that fostering a growth mindset is supportive of student academic success.

This study supports a focus on a growth mindset in the design standard. Improved self-efficacy found in the study shows that this design standard is internally consistent. Finally, the study is situated in a community college statistics course, which matches part of the DCMP framework.

Standard 3: Communication

Cardetti, F., & LeMay, S. (2019). Argumentation: Building students' capacity for reasoning essential to learning mathematics and sciences. *PRIMUS, 29*(8), 775–798.

This paper described an interdisciplinary collaboration to improve mathematical communication in college classrooms. The authors reviewed the literature supporting the importance of communication for learning mathematics and science. They defined five types of tasks in which students' mathematical communication competency is crucial for meaning making:

1. Making sense of procedures
2. Analyzing misconceptions
3. Tying concepts together
4. Connections to prior knowledge
5. Connections between representations

The authors gave examples of specific tasks in lower level undergraduate mathematics courses.

This paper supports the approach to communication in the design standard, particularly evaluating mathematical or statistical information, explaining mathematical concepts, and connecting course content to lived experience.

Finkenstaedt-Quinn, S. A., Petterson, M., Gere, A., & Shultz, G. (2021). Praxis of writing-to-learn: A model for the design and propagation of writing-to-learn in STEM. *Journal of Chemical Education, 98*(5), 1548–1555.

The authors implemented a write-to-learn model that removed both student and instructional barriers in the practice of STEM. The writing assignments asked students to apply what they learned in an authentic context and included peer review and revision. The faculty were supported by a faculty learning community. The authors found that the assignments improved students' conceptual and disciplinary learning.

This paper supports the inclusion of writing to learn and writing in response to authentic contexts incorporated in the design standard.

Standard 4: Technology

Piercey, V. I. (2017). A quantitative reasoning approach to algebra using inquiry-based learning. Numeracy: *Advancing Education in Quantitative Literacy, 10*(2).

The author presented a framework for teaching algebraic manipulations through a quantitative reasoning lens. This framework used authentic, realistic scenarios requiring the use of algebra and incorporating spreadsheets. Problems involved scenarios such as creating a spreadsheet to calculate a desired measure using observable data, or finding the values in a missing column in a spreadsheet.

Students who took the course were initially placed into Beginning Algebra. Those students completed a set of four algebraic manipulation problems at increasing levels of difficulty. The percentage of those solving each exercise correctly was compared to the same percentage with the same problems in Beginning Algebra, Intermediate Algebra, Precalculus, and Calculus. The percentage of students who completed the course incorporating this framework was close to the same rate for students in Calculus.

This paper supports the design standard in the argument that technology can help students think deeply about mathematical ideas and that technology does not need to replace procedural hand computations.

Cullen, C. J., Hertel, J. T., & Nickels, M. (2020, April). The roles of technology in mathematics education. *The Educational Forum, 84*(2), 166–178.

The authors identified four roles that technology plays in learning mathematics:

1. Promoting cycles of proof: Using technology to experiment with examples, form and test conjectures, and identify hypotheses
2. Presenting and connecting multiple representations: Examining connections between numerical, verbal, algebraic, and graphical representations of mathematical objects
3. Supporting case-based reasoning: Providing examples that students can explain mathematically and in context
4. Serving as a tutee: Giving students a tool with which to communicate their thinking

This paper supports using technology to focus on deeper mathematical and statistical concepts present in the design standard.

Standard 5: Context and Interdisciplinary Connections

Piercey, V. I. (2017). A quantitative reasoning approach to algebra using inquiry-based learning. *Numeracy: Advancing Education in Quantitative Literacy, 10*(2).

The author presented a framework for teaching algebraic manipulations through a quantitative reasoning lens. This framework used authentic, realistic scenarios requiring the use of algebra and incorporating spreadsheets. Problems involved scenarios such as creating a spreadsheet to calculate a desired measure using observable data, or finding the values in a missing column in a spreadsheet.

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This paper supports the design standard by demonstrating the value of focusing on data in realistic contexts.

Wang, X., Lee, Y., Zhu, X., & Okur Ozdemir, A. (2021). Exploring the relationship between community college students' exposure to math contextualization and educational outcomes. *Research in Higher Education*, 1–28.

The authors' study was based on the premise from the literature that to improve student success in community colleges, offering support structures was not enough—one must reform what is done in the classroom, particularly in mathematics classes. The authors performed a comparative study of student outcomes between mathematics classes that offered contextualization and traditional mathematics classes. Contextualized mathematics was defined as courses that (a) are centered on understanding and applying mathematical concepts, learning about the context involved, developing work-related skills, and challenging students to figure things out independently; and (b) used authentic applications of mathematics within realistic contexts on a regular and systematic basis. The study included 170 students in the contextualized courses, and 4,383 students in the traditional courses.

Controlling for other factors, the study found that relative to students in a traditional mathematics course, students in the contextualized course were:

- 2.55 times more likely to pass the course,
- 1.7 times more likely to continuously enroll in college, and
- 3.16 times more likely to complete a degree.

This study supports the emphasis on realistic contexts and deeper mathematical thinking inherent in the design standard. The study associates contextualization, based on a similar definition as in the design standard, to successful college completion at the community college level.

Reyes, J., Insorio, A. O., Ingreso, M. L. V., Hilario, F. F., & Gutierrez, C. R. (2019). Conception and application of contextualization in mathematics education. *International Journal of Educational Studies in Mathematics, 6*(1), 1–18.

The authors used a semistructured interview process to interview students of 25 geometry teachers in secondary schools in the Philippines. The study verified a conceptual framework in which contextualization combined mathematical concepts and applications to improve student understanding. The authors found two consistent themes in the interviews: the value of seeing connections to one's life and making connections to one's local environment.

This study supports the emphasis in the design standard on realism, using authentic and not contrived contexts and problems, and keeping the contexts timely.

Standard 6: Assessment

Morris, R., Perry, T., & Wardle, L. (2021). Formative assessment and feedback for learning in higher education: A systematic review. *Review of Education, 9*(3), e3292.

The authors performed a systematic review of the literature on formative assessment in higher education and found that the studies provided causal evidence that formative assessment improved student learning. However, the evidence was minimal. Out of the 188 studies that qualified for the authors' review, only 28 studies were robust. The remainder had significant limitations, such as a small sample size or a study based on a single instructor. The authors concluded that more systematic research was necessary.

This study, while limited, provides evidence that supports the role of formative assessment in the design standard.

Krause, A. J., Maccombs, R. J., & Wong, W. W. (2021). Experiencing calculus through computational labs: Our department's cultural drift toward modernizing mathematics instruction. *PRIMUS, 31*(3–5), 434–448.

The authors implemented a reform in their calculus courses where students were given assessments consisting of "labs," collaborative assignments using realistic applications and contexts. In interviews, students reported that the labs provided an enriching environment and enhanced their learning. The authors found that initial engagement among students was strong but declined throughout the semester. The decline was attributed to the limited nature of the reform, which took place at Michigan State University, a large R1 institution. Calculus courses were offered in large lectures with small sections that met for one hour per week in a recitation. To accommodate the large number of students taking calculus and to ensure the reforms were sustainable, the intervention was limited to recitation sections. Based on student surveys and interviews, the authors concluded that the constraints introduced by this limitation reduced the impact, suggesting that a more comprehensive and systemic reform could make the labs more impactful.

This study supports the use of realistic and authentic assessments included in the design standard, as the approach to assessment is encapsulated in a comprehensive and systemic environment (the other design standards) consistent with the nature of the assessments.