Curriculum Design Standards

Selected supporting research

Dana Center Mathematics PATHWAYS

An annotated bibliography **Summer 2014**

Overview

Dana Center staff[1] have developed these annotated citations as a resource for practitioners and other professionals interested in learning more about the research underpinning the Dana Center Mathematics Pathways (DCMP) model. This bibliography is one of three related bibliographies that explore the research literature that informs the following DCMP core ideas:

- The DCMP's four fundamental principles[2]
- **The DCMP's eight curriculum design standards**[3]
- The DCMP's *Frameworks for Mathematics and Collegiate Learning* course's four pillars (or themes).[4]

This document looks at the research in which the DCMP's eight curriculum design standards are grounded.

About this bibliography

This bibliography summarizes selected research that informs the DCMP's eight design standards that shape the development of every mathematics course authored by DCMP developers.

These eight standards guide how the curricular materials for individual DCMP mathematics courses have been designed to support learning and success for developmental mathematics students. The standards are used by developers to build curricular materials and by reviewers to ensure that the materials are true to the DCMP vision. These standards also describe the pedagogical and curricular practices that should be present in any course following the DCMP model.

Note that these citations are not alphabetically ordered; instead, they are sequenced for sensemaking—to illuminate, for example, the historical development of a concept, or to illustrate the connections among research findings on a given concept.

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[1] See last page of this document for acknowledgments.

[2] The DCMP's four fundamental principles are described here: https://dcmathpathways.org/dcmp.

[3] The DCMP's eight curriculum design standards are described here: https://dcmathpathways.org/resources/curriculum-design-standards-selected-supporting-research-annotated-bibliography.

[4] The DCMP's *Frameworks for Mathematics and Collegiate Learning* course's four pillars (or themes) are described here: https://dcmathpathways.org/resources/dcmp-frameworks-mathematics-and-collegiate-learning-selected-supporting-research.

DESIGN STANDARD I: STRUCTURE AND ORGANIZATION OF CURRICULAR MATERIALS

The Dana Center Mathematics Pathways curricular materials are organized around broad mathematical concepts rather than specific skills and topics. A primary goal of the DCMP curriculum is the development of conceptual understanding and strategies for problem solving.

The DCMP reconceptualizes traditional course structure around larger areas of focus that emphasize relationships between topics rather than the presentation of skills and topics in isolation. The following studies highlight the need for curricular materials with nontraditional structure and organization.

Stigler, J. W., Givvin, K. B., & Thompson, B. J. (2010 May). What community college developmental mathematics students understand about mathematics. *Math*AMATYC *Educator, 1*(3), 4–16. Retrieved from http://www.carnegiefoundation.org/sites/default/files/elibrary/MathAMATYC_Stigler.pdf

This study focuses on the growing number of students placed in developmental mathematics courses. The authors analyzed 20 years of California community college mathematics placement exam data with the goal of better understanding students' mathematical thinking and knowledge.

The study found that students often have stronger abilities to use memorized procedures than they do conceptual reasoning techniques. In addition, they found that students who demonstrated some ability to use conceptual reasoning were able to generate a higher number of correct answers than did students who lacked conceptual reasoning skills.

The findings in this study support the DCMP principle that a primary goal of mathematics curriculum should be to develop a conceptual understanding of mathematical reasoning and strategies for problem solving.

Givvin, K. B., Stigler, J. W., & Thompson, B. J. (2011). What community college developmental mathematics students understand about mathematics, Part 2: The interviews. *Math*AMATYC *Educator, 2*(3), 4–18. Retrieved from http://www.carnegiefoundation.org/sites/default/files/MathAMATYC_2011.pdf

This report is Part 2 of the 2010 mathematical skills study by Stigler, Givven, and Thompson. The authors believe that though students rarely use conceptual reasoning on placement exams, students are capable of developing these skills under the right circumstances.

To further investigate students' mathematical thinking processes, the authors conducted 30 interviews with students in developmental mathematics courses in California community colleges. Through these student interviews, the authors identified three classroom elements that they felt would improve students' conceptual reasoning abilities: 1) creating classroom tasks that focus more on problem solving and that use questions that defy the use of rote procedures in order to develop students' critical thinking skills; 2) making concepts and connections between concepts clear to help students organize mathematical thinking; and 3) reintroducing mathematical procedures while constantly maintaining connections to the concepts that underlie them.

This study's findings support the DCMP principle that curricula should be structured and organized to aid in the development of conceptual understandings and strategies for problem solving. These findings also support the DCMP principle that concepts should be linked through a variety of instructional strategies and connections rather than treated as isolated discrete topics.

Cullinane, J., & Treisman, U. (2010).[5] ***Improving developmental mathematics education in community colleges: A prospectus and early progress report on the Statway Initiative*. Paper presented at the 2010 NCPR Developmental Education Conference, New York, NY.**
Retrieved from http://www.postsecondaryresearch.org/conference/PDF/NCPR_Panel4_CullinaneTreismanPaper_Statway.pdf

This report describes the Statway project and the state of developmental mathematics at the time the report was written. Many students who enter a mathematics pathways program will have already experienced failure, often in more than one mathematics course.

For this reason, Cullinane and Treisman recommend the following principles of instructional design: The work in a pathways course should be challenging, reference students' prior knowledge, and focus on conceptual understanding. Courses should provide timely feedback and opportunities for practice in multiple contexts, and they should focus on mathematical communication.

These recommendations fit well with several DCMP design standards, but most importantly, they reinforce the idea that the traditional structure of developmental mathematics courses should be reconceptualized.

[5] Disclosure: Both Cullinane and Treisman were—and continue to be—integral to the creation and scaling of the Dana Center Mathematics Pathways model.

Design Standard II: Active Learning

The DCMP model is designed to actively involve students in analyzing data, constructing hypotheses, solving problems, making connections, and reflecting on their work and learning.

The DCMP active-learning design standard extends to classroom activities, instructor supports, and out-of-class work. In the DCMP model, students should be actively engaged in tasks using a variety of instructional strategies, and a portion of in-class time should be devoted to active-learning tasks. The following studies highlight the need for active learning in developmental education.

Carlson, K. A., & Winquist, J. R. (2011). Evaluating an active learning approach to teaching introductory statistics: A classroom workbook approach. *Journal of Statistics Education, 19*(1), 1–23.

> This study evaluates an active-learning approach to teaching introductory statistics over the course of a semester. Students in this course completed daily, in-class learning activities bookended by short lectures.
>
> Based on a survey of 60 students, Carlson and Winquist argue that students who experienced this active-learning approach showed significant, positive changes in their attitudes toward statistics. These attitude changes were associated with improved overall GPA and with improved performance on the statistics final exam. The positive results of this curriculum intervention suggest that activity-based approaches can improve both student attitude and student performance.
>
> This study supports the DCMP principle that students should be actively involved in tasks related to mathematics using a variety of instructional strategies.

Goldstein, L. B., Burke, B. L., Getz, A., & Kennedy, P. A. (2011). Ideas in practice: Collaborative problem-based learning in intermediate algebra. *Journal of Developmental Education, 35*(1), 26–37.

> The goal of developmental education is to ensure student success in subsequent college courses. This paper looks at a pilot aimed to optimize student success in college algebra or subsequent college-level math courses through increased opportunities for active learning. The study compares an intermediate-level developmental algebra pilot program to traditional intermediate-level developmental algebra courses taught by the same instructor in the same public university. The pilot differed from the more traditional course by including collaborative, problem-based learning, frequent group work, and a capstone project.
>
> Academic performance in the pilot and in the traditional intermediate algebra courses was indistinguishable; however, success in College Algebra was significantly higher for students who had participated in the pilot compared to those students who completed a traditional, lecture-based intermediate algebra course with the same instructor. This article supports the DCMP principle that students should be actively engaged in tasks using a variety of instructional strategies and that a portion of in-class time should be

devoted to active-learning tasks. It also supports the DCMP principle that students should have opportunities to develop problem-solving skills in developmental mathematics courses.

Design Standard III: Constructive Perseverance

The Dana Center Mathematics Pathways model supports students in developing the tenacity and persistence necessary for learning mathematics. The DCMP's curriculum and classroom activities provide opportunities for students to explore challenging mathematical and statistical concepts. By scaffolding lessons, allowing students to struggle, encouraging self-reflection, and providing advice and guidance, instructors can help students build perseverance and confidence in their ability to learn new material. The following studies highlight the need for constructive perseverance in developmental education.

Dweck, C., Walton, G. M., Cohen, G. L., Paunesku, D., & Yeager, D. (2011). ***Academic tenacity: Mindset and skills that promote long-term learning.*** **Paper prepared for the Gates Foundation. Seattle, WA: Bill & Melinda Gates Foundation. Retrieved from http://www.stanford.edu/~gwalton/home/Welcome_files/Dweck,%20Walton,%20%26%20Cohen,%202011.pdf**

In this paper the authors bring together a large body of research from the field of motivation studies that relates to the concept of academic tenacity.

Academic tenacity, also referred to as *perseverance*, is the ability to "look beyond short-term concerns to longer-term or higher-order goals, and to withstand challenges and setbacks to persevere toward these goals" (p. 5). Research has shown that student motivation can be positively affected by focusing on long-term goals over short-term goals and on community success over individual success, and by encouraging a sense of belonging and strengthening students' self-regulatory skills.

A growth mindset with regard to intelligence (i.e., the idea that you can improve your intelligence with effort) also positively affects academic tenacity. Interventions focused on teaching students about the growth mindset (p. 24), strengthening students' self-regulation through teaching student success skills (p. 34), showing the relevance of the work to students' lives and identities (p. 31), and encouraging feelings of social belonging in students (p. 28) have been found to positively affect student motivation and performance.

These interventions can be designed as a separate entity or integrated into content area coursework. The authors also cite research recommending that schools and teachers should have high expectations for their students, employ instructional scaffolding, offer motivational tools, create a welcoming environment, and support students' sense of autonomy (for example, by saying "you did well"—suggesting that your autonomous actions led to this outcome—versus "you are smart"—suggesting that your fixed identity, over which you have no control, led to this outcome).

This paper supports the DCMP principle of constructive perseverance. The DCMP designs curricula for developmental mathematics in which the students struggle with difficult concepts, receive academic scaffolding to support their learning, and develop their academic identity through student success skills and other tools.

Barragan, M., & Cormier, M. S. (2013). Enhancing rigor in developmental education. *Inside Out, 1*(4), 1–5. Retrieved from http://ccrc.tc.columbia.edu/media/k2/attachments/enhancing-rigor-in-developmental-education.pdf

This publication from the Community College Research Center's Scaling Innovation project examines the ways in which faculty are working to increase rigor within reformed developmental education classrooms.

Based on faculty and student interviews and classroom observations, the authors determined three strategies for increasing rigor in the developmental education classroom:

"(1) aligning developmental course content with college-level course expectations, (2) providing consistent opportunities for students to construct knowledge [including problem solving, critical thinking, reasoning, and making predictions], and (3) making struggle a part of the learning process" (p. 1).

The benefit of increasing the rigor and struggle in developmental coursework is that through struggling and succeeding, students become more confident. Preliminary findings from several colleges show that students in courses with this type of rigor were better able to persist and perform.

The authors found that increasing classroom rigor was often uncomfortable for students and faculty alike, as new pedagogies and new expectations were often unfamiliar. These concerns make scaffolding for students and support for faculty integral to the success of these efforts.

Faculty concerns were lessened when they could interact with other faculty who were experiencing the same changes. Some students in the study worried that the struggle was a sign of weakness. By introducing the growth mindset, teachers were able to reframe student struggle into a positive.

This report supports the DCMP principle that students must develop the tenacity and persistence necessary for learning math. It also supports the idea that students who are struggling with difficult content must be supported through academic scaffolding as well as through information about learning and growth mindsets.

DESIGN STANDARD IV: PROBLEM SOLVING

The DCMP model supports students in developing problem-solving skills in which they apply previously learned skills to solve nonroutine and unfamiliar problems. Problem solving is a key component of the DCMP curricular materials, and students regularly complete tasks that allow for the use of multiple strategies and solution methods. Classroom activities and lessons enable students to work through various problem-solving strategies with instructors and reflect on solution methods. The following studies highlight the need for cultivating problem-solving skills in developmental education.

Piatek-Jimenez, K., Marcinek, T., Phelps, C. M., & Dias, A. (2012). Helping students become quantitatively literate. *Mathematics Teacher, 105*(9), 692–696.

This article suggests that it is important for mathematics courses to help students develop quantitative literacy in addition to specific mathematical skills. Many students and graduates are unable or reluctant to quantitatively reason and make informed decisions in everyday situations.

To be quantitatively literate, a person must develop "the ability to solve real-life problems using a quantitative perspective" (p. 692).

The authors recommend incorporating quantitative literacy into course content through the use of magazines, newspapers, student journals, textbooks, and students' real-life decision making.

This article supports the DCMP principle that students should develop problem-solving skills to help them use prior knowledge and quantitative literacy skills to solve real-world problems as well as the Design Standard V of placing work in context.

Verhovsek, E., & Striplin, T. (2003). Problem based learning: Applications for college mathematics and allied health. *Mathematics and Computer Education, 37*(3), 381–387.

This study, which involved nine faculty and 700 students, tested the effectiveness of a grant-funded effort to include problem-based learning directly relevant to the health sciences in developmental mathematics courses.

The authors found that students enrolled in problem-based learning courses performed significantly better on post-course examinations and improved their ability to collaborate with others compared to students in traditional developmental courses. The authors include research that describes further benefits of problem-based learning, including increased student achievement, improved teamwork, increased student engagement, and a greater emphasis on synthesis and other higher-order thinking skills.

This study supports the inclusion of problem solving throughout all DCMP mathematics curricula. It also supports the DCMP principles that students should develop their problem-solving skills and that mathematics coursework should be relevant to other disciplines and to the real world.

DESIGN STANDARD V: CONTEXT AND INTERDISCIPLINARY CONNECTIONS

The DCMP mathematics curricula present mathematics in context and connect mathematical concepts to various disciplines. These curricula use real data related to diverse disciplines so that students can practice a realistic application of the skills needed to connect mathematical and statistical concepts to other disciplines and the real world. The following studies highlight the need for context and interdisciplinary connections in developmental education.

Perin, D. (2011). Facilitating student learning through contextualization: A review of the evidence. *Community College Review, 20*(10), 1–28.

This article is the result of a literature review of 61 sources on contextualized learning. Contextualization is defined here as "an instructional approach that connects basic skills and academic or occupational content" (p. 2).

Findings suggest that many learners struggle to connect basic reading, writing, and mathematical skills to other disciplines because of a lack of motivation to learn basic, seemingly isolated skills at the developmental level and a lack of support to improve these basic skills in specific disciplines.

The author argues that the contextualization of basic skills can support students in the development of basic academic skills and in long-term college achievement. This article supports the DCMP principle that content in basic mathematics courses should be connected to other disciplines and the real world.

Wiseley, W. C. (2011). *Effective basic skills instruction: The case for contextualized developmental math* (Policy Brief 11-1). Stanford, CA: Policy Analysis for California Education.

The author of this study investigates the use of contextualized developmental mathematics courses at 110 community colleges in California. The study finds contextual courses to be both effective and rare. The author argues "pressure for traditional academic courses has eliminated many contextualized courses" (p. 2).

The author also argues, however, that low success rates in traditional developmental courses show that students have a need for more contextualized and applicable options. The study found that math courses with contextualized content created an academic environment in which students completed developmental math courses in higher percentages than did students taking traditional developmental math.

Moreover, the author also found that students in contextualized courses "attempted and passed degree-applicable courses at higher rates" (p. 4) and were "more likely to continue on to degree-applicable transferable courses the subsequent semester" (p. 8).

The findings support the DCMP principle that developmental mathematics curricula should be contextualized and include mathematical and statistical content that can be related to real-world contexts and other disciplines.

Teeguarden, J. (2013). Beyond the textbook: Getting developmental students involved in learning. *Math*AMATYC *Educator*, 4(2), 9–13.

Teeguarden argues that traditional developmental mathematics instruction has limited students' exposure to authentic, real-world problem solving. The author cites leaders in the field who support the use of problems in context to engage students and support their understanding.

This article gives multiple examples of ways to include authentic data in developmental mathematics curricula. These examples include problems that can be created using authentic data that would be relevant to a student population, including credit card debt, the cost of appliances, and the fat content of food.

This article supports the DCMP principle that mathematics curricula should present math in context and connect it to various fields.

Silva, E., & White, T. (2013). *Pathways to improvement: Using psychological strategies to help college students master developmental math*. Stanford, California: Carnegie Foundation. Retrieved from http://www.carnegiefoundation.org/sites/default/files/pathways_to_improvement.pdf

This report by the Carnegie Foundation for the Advancement of Teaching tests strategies to help students persist and succeed academically. The authors argue that in addition to the necessity for *productive persistence* (also known as *constructive perseverance*, discussed under DCMP Design Standard III above), curriculum should be relevant: "When work is relevant, students are often more motivated and more likely to persist in the face of difficulty" (p. 11).

The authors describe several examples of the use of relevant coursework, activities, and strategies that resulted in positive effects on students' interest levels and course grades. This study supports the DCMP principle that developmental mathematics curricula and content should be contextualized and connected to various fields.

Design Standard VI: Use of Terminology

The DCMP uses discipline-specific terminology, language constructs, and symbols to intentionally build mathematical and statistical understanding and to ensure that terminology is not an obstacle to understanding.

This design standard recommends that mathematics terminology be included in the introduction of new material, in the instruction and clarification of concepts, and in student-to-student and written communication during classroom activities.

The following studies highlight the need for the intentional use of terminology in mathematics education generally, and in one case, in developmental education specifically.

Harmon, J. M., Hedrick, W. B., & Wood, K. D. (2005). Research on vocabulary instruction in the content areas: Implications for struggling readers. *Reading & Writing Quarterly*, *21*(3), 261–280.

> This article provides research on content vocabulary and the role it plays within a classroom setting and in learning outcomes. The authors suggest that categorizing mathematical terms can help instructors "understand the cognitive demands placed on students as they struggle with terminology presented in textbooks" (p. 267) and terminology introduced through instructor explanations.
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> Research on mathematical vocabulary argues that teachers should focus on improving students' ability to read mathematics with comprehension. The authors provide several research-based strategies for instruction to help students build these skills.
>
> They argue that teachers should make students aware of relevant terminology, inform students that the meaning of mathematics vocabulary can change based on context, and include a focus on conceptual understanding as well as definitional knowledge (p. 268).
>
> Finally, teachers should assist students in learning how to use the textbook as a tool for learning and for building mathematical reasoning, rather than relying solely on oral explanations of concepts. The findings in this article support the DCMP principle that students need to use mathematical terminology and symbols to build greater mathematical and statistical understanding.

Dunston, P. J., & Tyminski, A. M. (2013). What's the big deal about vocabulary? *Mathematics Teaching in the Middle School, 19*(1), 38-45.

This article by two Clemson University mathematics professors explores how teaching vocabulary to middle school students can enhance their conceptual understanding and set the foundation for appropriate mathematical discourse. The authors present several research-based approaches to teaching vocabulary in middle school mathematics courses and conclude that teaching mathematics vocabulary is essential for conceptual understanding.

They argue that teaching mathematics terminology successfully allows students to "expand their abstract reasoning ability and move beyond operations to problem solving" (p. 40) in higher levels of mathematics and in everyday life.

Though the article focuses on middle school mathematics, these lessons and approaches can be applied to developmental courses as well. This article supports the DCMP principle that when terminology is included in mathematics curricula it can have a positive effect on student comprehension and achievement in math.

Gay, A. S. (2008). Helping teachers connect vocabulary and conceptual understanding. *Mathematics Teacher*, *102*(3), 218–223.

The author of this article, an associate professor of mathematics education at the University of Kansas, argues that mathematics vocabulary must be part of a teacher's instructional plans to develop students' understanding of key ideas. Students need to know the meaning of mathematics vocabulary words in order to understand and communicate mathematical ideas, thus building mathematical literacy.

The author suggests strategies to help students learn vocabulary, including a graphic organizer that associates math vocabulary words with the characteristics of a concept, with visual images, and with the word's definition. The author argues that vocabulary instruction should be an integral part of preservice teacher training to build teacher awareness of how their use of vocabulary directly contributes to students' understanding of mathematical concepts.

While the author is speaking primarily to teachers of high school and middle school mathematics, these suggestions are also relevant to the needs of developmental math students. These suggested practices relate to the DCMP principle that students need to use discipline-specific vocabulary, language concepts, and symbols to build mathematical and statistical understanding. In addition, the practices described support the DCMP principle that vocabulary should not be an obstacle to understanding. Curricular materials should include intentional instruction on the use of mathematical terminology and should enable students to make connections between concepts.

DESIGN STANDARD VII: READING AND WRITING

The Dana Center Mathematics Pathways develop students' ability to communicate about—and with—mathematics and statistics in contextual situations appropriate to the students' mathematics pathway. The DCMP curricular materials provide students with opportunities to discuss, analyze, and think critically about mathematics and statistics.

The curriculum requires students to engage with mathematical and statistical concepts through authentic contextual reading and writing tasks. The activities are scaffolded to support students in developing the required reading and writing skills. The following studies highlight the need for a stronger focus on reading and writing in mathematics and other disciplines to support students in developmental education.

Baer, J. D., Cook, A. L., & Baldi, S. (2006). *The literacy of America's college students*. Washington, DC: American Institutes for Research. Retrieved from http://www.air.org/sites/default/files/downloads/report/The20Literacy20of20Americas20College20Students_final20report_0.pdf

The National Survey of America's College Students (NSACS) examines the literacy of U.S. college students through a national sample, focusing on document literacy, prose literacy, and quantitative literacy. The 2003 survey found that college students, both at community colleges and at four-year universities, struggle the most with quantitative literacy.

Quantitative literacy refers to the ability to comprehend numbers embedded in written materials, including statistical studies. Students in developmental programs at two-year colleges, especially students in developmental mathematics, had significantly weaker quantitative literacy skills than students who did not need developmental coursework. The study also found that the literacy gap between students of color and white students persists in colleges.

This article supports the DCMP principle that students must develop the knowledge and skills required to perform quantitative literacy tasks, including basic reading and writing. Students must be provided with opportunities to discuss, analyze, and think critically about mathematics and statistics in authentic contexts, including through reading and writing.

Perin, D. (2013). Literacy skills among academically underprepared students. *Community College Review*, *41*(2), 118–136.

This article examines more than 200 studies published between 2000 and 2012 focusing on strategies to improve the literacy levels of college students in developmental programs. The key finding is that significant research is still needed to learn about the literacy capabilities of developmental students and how the incorporation of reading and writing can help improve these skills.

The author recommends explicit literacy instruction in content-area courses, especially instruction in specific literacy strategies, including both reading and writing instruction when these tasks are embedded within the content assignments. The author also recommends referring students to tutoring centers and other academic learning centers for tutoring in course-related reading and writing (p. 125).

These strategies fit with the DCMP principle that students should develop the ability to communicate about and with mathematics by using curricular materials that provide students with the opportunity to discuss, analyze, and think critically about mathematics in an authentic context. Basic reading and writing skills are an integral part of this process and should be addressed in course materials.

McConachie, S., Hall, M., Resnick, L., Ravi, A. K., Bill, V. L., Bintz, J., & Taylor, J. A. (2006). Task, text, and talk: Literacy for all subjects. *Educational Leadership, 64*(2), 8–14.

This article focuses on the ways that disciplinary literacy can be used in mathematics, history, and science classrooms to improve content-area knowledge as well as basic literacy. The authors begin by describing the literacy gap that exists for many students, and describe the hesitation that many teachers feel about incorporating "generic reading and writing strategies" (p. 8) in their classrooms.

The authors explain that disciplinary literacy is meant to be more content specific and is "based on the premise that students develop deep conceptual knowledge in a discipline by using reading, writing, communication, and critical thinking related to the topic at hand"
(p. 8).

The authors argue for content-specific literacy instruction and include classroom vignettes to illustrate the principles of the Disciplinary Literacy instructional framework developed by the Institute for Learning at the University of Pittsburgh in 2002. This framework describes best practices for teachers' relationships with students, classroom culture, and instructional pedagogy and includes ways to weave disciplinary literacy into all of these areas. This article supports the DCMP's use of authentic reading and writing tasks within mathematics course content.

DESIGN STANDARD VIII: TECHNOLOGY

The DCMP mathematics curricula use technology to facilitate active learning by enabling students to directly engage with and use mathematical concepts. Technology should support course learning objectives and, in some cases, the use of technology can be a learning objective in itself. The DCMP model recommends that students have access to calculators, computers, and the Internet both inside and outside the classroom. The following studies highlight the need for the incorporation of technology in developmental education.

Epper, R. M., & Baker, E. D. (2009). Technology solutions for developmental math: An overview of current and emerging practices. *Journal of Developmental Education, 26*(2), 4–23.

This report examines the challenges of developmental mathematics in community colleges and "the potential of technology to address these challenges" (p. 3). The authors identify various community college projects and curricular innovations since 2004 and explore the role that technology plays in supporting teaching and learning in developmental math.

The authors found that effective developmental education programs in community colleges combined research-based approaches that support developmental math students. By examining course and curricular redesign efforts, the authors found that technology is most effective when it is specifically incorporated into curriculum, rather than left as an add-on.

Curriculum should align technology to learning objectives and include an appropriate interaction between instruction and technology. This report reinforces the DCMP principle that technology should support learning objectives. Technology can facilitate active learning by supporting students so that they may engage more deeply with and use mathematical and statistical concepts.

Adams, T. L. (1997). Technology makes a difference in community college mathematics teaching. *Community College Journal of Research and Practice, 21*(5), 481–491.

This article examines the effects of using graphing calculators—as a technological tool for instruction—on students' oral and problem-solving assessment outcomes in community college mathematics classes.

The author found that the use of graphing calculators allowed for more meaningful assessment by the instructor through encouraging more oral discourse and creating more opportunities for problem solving in the classroom.

The results of the study indicate the potential for technological tools to influence teachers' practices of alternative assessment in the mathematics classroom. This article supports the DCMP principle that technology should be used to support students in learning mathematical objectives.

MacDonald, L., Vasquez, S., & Caverly, D. C. (2002). Techtalk: Effective technology use in developmental mathematics. *Journal of Developmental Education, 26*(2), 36–37.

This article focuses on the effective use of technology in developmental mathematics classrooms. Specific technology discussed includes graphing calculators, the Internet, and Excel and other spreadsheet applications.

Technology that enables students to collect, analyze, and interact with data can help build critical-thinking skills and boost understanding of concepts. Technology that allows students to learn mathematical modeling skills, gather physical data, analyze data, think quantitatively, visually see and interact with results, or receive instant feedback on work can be a positive addition to developmental classrooms by helping students interact with and understand material more deeply.

This article reinforces the DCMP principle that students should have access to technology, which supports and facilitates active learning by enabling them to engage with and use mathematical concepts.

Vásquez-Mireles, S., Westbrook, T., Ward, D., & Diaz, C. R. (2013). An investigation of technological options in developmental mathematics. *Math*AMATYC *Educator, 4*(2), 57–61.

This paper focuses on the uses and effectiveness of using various types of technological applications, including graphing calculators, PowerPoint, YouTube, and other Internet-based resources, in the developmental mathematics classroom. Through a quasi-experimental design, the authors investigate the relationship between the incorporation of various technologies in developmental mathematics classrooms and student outcomes. Looking at four specific mathematical topics, including systems of linear equations, radical expressions, radical equations, and quadratic equations, the analysis suggests that “regular infusion of technology supports academic performance and does not hinder basic skills” (p. 60).

The use of technology was particularly effective for quadratic equations and radical expressions; the article describes that use of technology when students were learning these concepts improved their academic performance. The authors suggest that these positive results are linked to students’ ability to visually interact with mathematical content. This study highlights the need for technology in developmental mathematics classrooms and supports the DCMP principle that technology can be used to supplement other forms of instruction to improve student outcomes.

About this resource

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About these bibliographies

In these annotated bibliographies, we provide information on selected research underpinning the Dana Center Mathematics Pathways. These June 2014 bibliographies address:

- The DCMP's four fundamental principles that shape the overall initiative
- The DCMP's eight curriculum design standards that inform the design of all courses developed by the DCMP
- The DCMP's *Frameworks for Mathematics and Collegiate Learning* course's four pillars (or themes)

About the Dana Center

The Dana Center develops and scales math and science education innovations to support educators, administrators, and policy makers in creating seamless transitions throughout the K–14 system for all students, especially those who have historically been underserved.

We focus in particular on strategies for improving student engagement, motivation, persistence, and achievement.

The Center was founded in 1991 at The University of Texas at Austin. Our staff members have expertise in leadership, literacy, research, program evaluation, mathematics and science education, policy and systemic reform, and services to high-need populations.

For more information:

- about the Dana Center Mathematics Pathways, see **www.dcmathpathways.org**
- about the Texas Association of Community Colleges, see **www.tacc.org**