EXECUTIVE SUMMARY: Research Base of the CPM Educational Program, 2013

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In the seven years since the original CPM Research Report was posted, the new research has continued to validate the efficacy of the three pillars of CPM pedagogy:

1. Students learn ideas **more deeply** when they discuss ideas with classmates.
2. Students learn ideas **more usefully** for other arenas when they learn by attacking problems—ideally from the real world.
3. Students learn ideas **more permanently** when they are required to engage and re-engage with the ideas for months or even years.

These three principles (termed, respectively, as "cooperative learning," "problem-based learning" and "mixed, spaced practice") have driven the development of the CPM textbooks from the beginning and each year these principles are validated by more solid research to prove their effectiveness.

While the results of the more recent research are blended with older research in the sections that follow, it seems appropriate to highlight the major changes in the research findings.

1. The idea that students should engage in discussions with classmates as an integral part of learning mathematics (or most other subjects, for that matter) is no longer a serious topic of research. It is simply assumed to be true in the same way that the geological idea of plate tectonics is assumed today when forty years ago it was still a topic for debate. The research emphasis today is much more involved with the appropriate role of the teacher in classrooms where the concept of student discussion is put into practice. In particular, when should a teacher intervene with a team and how? These issues have been a topic of the professional development of new CPM teachers for 20 years, and we continue to refine our advice, but the new data supports our current practices.

In a related development, many more businesses, particularly those in newer fields (high tech, medical research, etc.) as well as those in traditional careers are also becoming more insistent that new hires must have "soft" skills such as the ability to work within a team environment, a skill that has not just attitude components but also involves the ability to listen to the ideas of others and to communicate your own. Individual competence is, of course, still valued, but employees are also being evaluated by his or her ability to work within a larger group since fewer and fewer jobs are done by lone wolves.

So the skills developed working within a team in a CPM classroom are not valuable solely for learning mathematics but are also skills that will be useful in a career. Learning how to communicate your ideas clearly and directly is a life skill that is taught, valued and supported in a CPM classroom. Listening to the ideas of others is necessary to be an effective team member whether you are in a mathematics

classroom or on a team to develop a new self-driving car or to stave off a new kind of business competitor.

2. It is now overwhelmingly accepted by the educational research community that a lecture is not an efficient way to learn ideas for long-term retention and use, even though most students are more comfortable with being told a process for solving a problem rather than thinking it through themselves. The evidence continues to mount that students of all ages and, more importantly, of all ability levels can profit from problem-based learning.

Much of the more recent research on learning mathematics and science has focused on identifying the best type of problem-based instruction to use, and the consensus is *assisted discovery*, where the problems to assist learning are carefully chosen and sequenced. The research is also showing that although students working alone can usefully learn from working on problems, it is more effective in the long term when this instructional style is paired with cooperative learning.

Note that students who are educated using a problem-based learning style are developing another useful soft skill—the attitude that they do not need someone else to tell them how to tackle a new problem—that is increasingly valuable in a world where most of them will have several different kinds of jobs in their lifetime.

3. Mixed, spaced practice has experienced the greatest increase in research support during the past half-dozen years. It was moderately well established 15 years ago that *massed practice* (doing 40 homework problems of the same type) was a less effective learning tool than *spaced practice* (i.e. taking the same 40 problems but having students space them out in homework over several days or weeks). Massed practice always seems a better way to learn, but it is not nearly as effective in the long term.

Now the notion of *mixed practic*e has been added as a natural complement to spaced practice; if the homework problems of one type are spread over several days, the homework for each day of necessity needs to incorporate problems of several different types. In dealing with this mixed homework, students now not only need to be able to recall how to solve a particular type of problem, but to identify the type as well. One skill is equivalent to being able to drive safely on several kinds of road (city street, freeway, mountain road) while the other is equivalent to being able to decide which route is the best. *Both* skills are needed to navigate life well and both need to be practiced on a regular basis.