Leading students to creatively develop mathematical models via leaky buckets

BRYNJA KOHLER AND JAMES POWELL
Utah State University, United States

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Suppose you have a bucket full of water with a hole in it, and you want to predict how long it will take for the bucket to empty. One can derive a slick first order differential equation for the height of the fluid as a function of time based on elementary physics as done by Torricelli in the 17th century – but how useful is such a model for practical purposes? In our experience this classical model is actually quite poor at capturing real data, creating ripe ground for problem-based learning. We have developed a laboratory exercise and modeling problem for undergraduate students in which they are challenged to come up with a better model than the classic. But a good problem doesn’t teach itself. We have also studied practical instructional strategies that mathematics educators have endorsed for maintaining a productive and challenging classroom atmosphere while groups of students work on cognitively demanding tasks at the elementary level. In our study, we observed that analogous instructional approaches are effective for keeping university students engaged at high levels of cognition while developing original mathematical models.