The flipped classroom is everywhere these days. This past August, every Costco member in the United States received the back-to-school edition of the member magazine—with Salman Khan on the cover and an article about the flipped classroom inside. Much of the conversation has been about video, content creation and delivery, and recuperation of class time.

First-year flippers often focus on making videos for students to watch before class, which provides more one-on-one time with students during class. This time-shifting of direct instruction results in higher student achievement and increased engagement.

But what about teachers who want to take this approach further? An important next step is flipping your classroom—for mastery.

How We Got There
In our first year of flipping the classroom (2007-08), we had students watch our direct instructional videos before coming to class. (Although we taught different sections of chemistry, we worked out this approach together and applied it in our separate classrooms.) The next day in class, students did more engaging activities, such as running interactive simulations like those available at phET (http://phet.colorado.edu). In a simulation on gas properties, for example, students pump gas molecules into a box and see what happens as they change the volume, add or remove heat, change gravity, and so on. We like to call this approach the Flipped Classroom 101.

Then, in the middle of our second year, we moved to a new phase. We fell into mastery learning when a school counselor approached one of us—Jon—in January 2008, asking whether a new student—one with no background in chemistry—could enter his chemistry course. In previous years, Jon would have said no, that a student couldn’t enter a yearlong course in the middle of the stream. But because we’d created videos for each lesson, Jon realized that the...
student could enter the class, work at her own pace, and learn. To our amazement, in one semester this student completed 80 percent of the entire year’s worth of chemistry.

What if all students, we wondered, had that opportunity to work through content at their own pace? What if all students had to master the content before they moved on? One problem we still faced, especially in our highly sequential chemistry course, was that when a student did poorly on a summative assessment, we still moved on. If a student earned a 42 percent on a test we gave Friday, on Monday we went on to the next topic.

So in spring 2008, we merged two concepts—flipped learning and mastery learning—and developed what we call the flipped-mastery model of education. In this model, students work through course content at a flexible pace, receiving direct instruction asynchronously when they’re ready for it. When they get to the end of a unit, they must demonstrate mastery of the learning objectives before they move on.

**Two Problems, Two Solutions**

For many years, time has been the constant in our schools; content mastery has depended on the amount of learning that takes place in that fixed period of time. However, on
we believe that learning should be the constant and time, the variable. This ensures that all students learn what they’re expected to learn but that they do so in the amount of time each one of them needs.

Bloom’s mastery learning approach is difficult to implement because of two logistical issues. First, if teachers need to deliver direct instruction, when do they deliver it if students are all at a different place in their learning? Actually, students in all classes are always at different places in their understanding, yet we continue to treat them as a homogeneous group. Mastery learning exposes and accepts this diversity, but logistics often prevent teachers from meeting learners’ individual needs.

The second challenge is assessment. How many versions of a summative assessment can a teacher realistically create? It just isn’t practical for the typical teacher with 30 students to type up multiple versions of exams and grade them manually.

Fast-forward to the information age and to the advent of two technologies: online video and learning management systems. The availability of online videos has solved the problem of direct instruction. YouTube, Vimeo, and other online video services now deliver videos on virtually any topic, and teachers can upload video content that’s accessible to anyone with an Internet connection.

As for the assessment challenge, teachers can now easily create online tests using learning management systems and online quizzing modules such as Moodle, BlackBoard, Canvas, My Big Campus, Schoology, Pathwright, Quia, and Haiku Learning. The assessments can differ each time a student takes an exam, which allows

### FIGURE 1. Unit on Gas Laws, Broken Down by Objectives, Learning Objects, and Required Activities.

<table>
<thead>
<tr>
<th>Learning Objectives</th>
<th>Learning Objects</th>
<th>Required Activities</th>
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<tbody>
<tr>
<td><strong>Gases 1</strong></td>
<td>Be able to understand how gases differ from solids and liquids and how gas pressure is measured.</td>
<td>Video 1&lt;br&gt;Worksheet 1&lt;br&gt;Text Section 12.1–12.2</td>
</tr>
<tr>
<td><strong>Gases 2</strong></td>
<td>Be able to conceptually and mathematically explain Boyle’s, Charles’s, and Gay-Lussac’s laws.</td>
<td>Video 2&lt;br&gt;Worksheet 2&lt;br&gt;Text Section 12.3</td>
</tr>
<tr>
<td><strong>Gases 3</strong></td>
<td>Be able to calculate using the combined gas law.</td>
<td>Video 3&lt;br&gt;Worksheet 3&lt;br&gt;Text Section 12.3</td>
</tr>
<tr>
<td><strong>Gases 4</strong></td>
<td>Be able to calculate using the ideal gas law.</td>
<td>Video 4&lt;br&gt;Worksheet 4&lt;br&gt;Text Section 12.4</td>
</tr>
<tr>
<td><strong>Gases 5</strong></td>
<td>Be able to conceptually and mathematically explain Dalton’s law of partial pressure and Graham’s law of diffusion.</td>
<td>Video 5&lt;br&gt;Worksheet 5&lt;br&gt;Text Section 12.5</td>
</tr>
<tr>
<td><strong>Gases 6</strong></td>
<td>Be able to do gas-stoichiometry problems in which gases are not collected at standard temperature and pressure.</td>
<td>Video 6&lt;br&gt;Worksheet 6&lt;br&gt;Text Section 12.6</td>
</tr>
<tr>
<td><strong>Gases 7</strong></td>
<td>Be able to determine the molar mass of a gas that is collected at nonstandard conditions.</td>
<td>Video 7&lt;br&gt;Worksheet 7&lt;br&gt;Text Section: Not in Text</td>
</tr>
</tbody>
</table>
for customized paths of study based on a student’s current abilities and understanding of content.

**How to Organize a Flipped-Mastery Model**

In the flipped-mastery model, the teacher begins by organizing content around specific objectives. As chemistry teachers, we analyzed each unit of study and broke each one down into the following categories:

- *Learning objectives* such as “be able to calculate using the combined gas law.”
- *Learning objects* that we would make available for students to use, such as videos, problem sets, and references to specific sections of the textbook.
- *Required activities* that students had to complete to demonstrate mastery for each objective, such as hands-on experiments, inquiry-based labs, teacher-led demonstrations, and online simulations.

Essentially, we gave students a menu of options they could use to learn the desired outcomes. (For a breakdown of our unit on gas laws, see Figure 1.)

Once we developed the list of objectives, we made one video for each objective, developed worksheets to help students practice what they had learned, assigned hands-on activities that supported the learning objectives, and developed summative assessments.

A word about the videos: We found that they worked best when we kept them short. We recommend making them no longer than 60–90 seconds per grade level. So if you’re making videos for 10th graders, for example, keep them under 15 minutes.

All this probably seems like a lot of work, but we’d already been using many of these items before we implemented the flipped-mastery model. We already had mountains of worksheets, many hands-on experiments we had used for years, and plenty of test questions on gas laws. We simply reorganized these items to fit the flipped-mastery model and made a more deliberate attempt to ensure that every question on every page helped students progress toward mastery.

One mistake we made at the outset was creating a video for every objective. In retrospect, we’ve come to understand that direct instruction isn’t always the best way for students to learn. For example, we found that videos weren’t particularly helpful in teaching about atomic theory; the topic was too abstract, and the videos just confused the students. As we modified and improved on the model, we began to add more inquiry activities and projects that helped students understand content more deeply. (For an example of inquiry activities, see POGIL [Process Oriented Guided Inquiry Learning] at www.pogil.org.)

Student engagement in activities like these brought about the greatest transformation.

We’re often asked whether teachers should create their own content or look for videos others have created. One of our core beliefs is that teaching is inherently about human interaction, about the teacher–student relationship. When teachers create their own videos, students recognize that their teacher is taking the time to “teach” them.

Consider the issue in terms of a continuum: At one end, on the left, teachers create all the videos and other learning objects; at the other end, on the right, they only use others’ products. We feel that teachers should err on the side of creating their own materials—they should stay well left of center—because of the relational aspect of teaching.

**How to Pace**

In an ideal world, students would master content at their own pace and move on when they’ve done so. All students would be self-starters and would be genuinely interested in all subjects.

This, of course, is not realistic. Like most schools, the school where we taught when we started flipping operated on a 9- to 10-month schedule in which we saw our students from August through May. So we had to set a schedule of benchmarks, but we allowed students to work at a flexible pace. We expected them to master three to four objectives each week. Each Monday, we told students what they needed to accomplish by the end of the week. We also gave them guidance about how much time the various activities would take so they could plan their week.

But we ran up against a problem: Slower learners weren’t mastering all the content. They weren’t able to keep up with our pacing guidelines, which were still a function of our traditional school calendar. We ended up having too many different class activities happening at the same time, which was a logistical nightmare. We almost gave up because of this.

**Using Moodle as our learning management system, we were able to generate thousands of different versions of our tests.**
In the spring of that first year of implementing flipped mastery, we devised a solution. We reorganized our list of objectives for each grading period to “front-load” the essential ones. We saved the “nice to know” objectives for the end of the grading period. For example, in our unit on gas laws, we expected all students to conceptually understand Graham’s law of diffusion but placed the more mathematical formulation of the law in the “nice to know” category. That way, when our slower learners fell behind, they weren’t missing the essential objectives, only the “nice to know” ones. When we started a new grading period, all students were back on the same page.

Note that the slower learners never went back and learned the “nice to know” objectives. We decided that we preferred that students deeply understand the essential objectives instead of being exposed to all of them. Our traditional calendar and some less-motivated students required us to modify a self-paced ideal into a flexible-paced reality.

How to Assess

Our biggest struggle in implementing the flipped-mastery model was assessment and grading. How could we honor the school’s grading system and still maintain the integrity of an approach that was driven more by competencies and mastery? Philosophically, we gravitated toward standards-based grading, but we lived in a community that understood and valued letter grades.

So we tackled grading in two ways, creating a system for both formative and summative assessments.

Formative Checks

The most important part of our assessment system was simple conversations we had with our students. When students felt they had mastered an objective, they approached us with their evidence, which usually included their worksheets, experiment write-ups, and notes from their interaction with an instructional video. We then asked them some key questions about what they had learned. We could quickly determine whether they truly understood a topic.

Often, during these formative checks we realized that students either had a misconception or were missing a crucial point. For example, students often misunderstood the nature of gravity, a misconception we easily discovered through questioning them. In those cases, we’d tell the student to rewatch a video, practice a few more problems, or dig deeper through more investigation.

We pushed our more advanced students to do deeper work. One student developed a fuel cell to charge her cell phone. We made sure our struggling students mastered the essential objectives by remediating with them one-on-one or in small groups, essentially working with them until they got it.

This individualized assessment is probably one of the greatest benefits of the flipped-mastery system. We were able to talk to every student in every class every day, and most of our discussions took place in these formative-check conversations.

Summative Retakes

In our flipped-mastery system, students could attempt a summative assessment as many times as they needed to demonstrate mastery. But if a teacher gives the same test over and over...
over, students simply memorize the test; they don’t necessarily learn the content. Moreover, a flipped-mastery summative assessment can be a logistical nightmare. How many versions of an exam can a teacher have in the filing cabinet, and how many hours will it take to grade each new attempt?

We were able to leverage technology to help us solve this problem. Using Moodle as our learning management system, we generated thousands of different versions of tests that assessed the same objectives. We each had seven netbooks in our class for students to use; they took their summative assessments in class after they had mastered each objective.

For each of the objectives shown in Figure 1, we created multiple questions that assessed each objective. In the case of this gas laws unit, we had seven banks of questions, one bank for each objective. When students took a summative assessment, the computer randomly picked one to two questions from each bank and generated a test. The software also graded the majority of the questions.

Because we strongly believe that education needs to be about human interactions, we wanted one more conversation with our students before we had them move on to the next topic. After students took an exam, they had to set up an appointment to come and visit with us. During that appointment, we went over the questions they had answered incorrectly and provided remediation and assistance to help them master the objectives they hadn’t understood. They retook the assessment once we were satisfied they had received the appropriate help.

We realize that these face-to-face interactions take a lot of time. But we were able to make the time by shifting all the low-level content delivery out of the classroom.

Interacting with so many individuals was certainly a greater challenge when we had larger classes. Some policymakers and administrators like the idea of the flipped classroom because they see it as a way to save money by having larger class sizes. They surmise that because we can outsource content to video, the teacher becomes less important and less busy and can handle a larger student load.

We disagree. In the flipped-mastery model, teachers are even more valuable. Their time in the class is maximized. The teacher’s main role is not to be a disseminator of knowledge, but rather a facilitator of learning.

**Students at the Center**

In our accountability-driven culture, mastery learning has a solid place in school. The flipped-mastery model allows for innovation yet maintains the integrity of content standards. Moreover, it leverages today’s technology to overcome the logistical hurdles of the past. This enables teachers to individualize learning for each student and puts student learning at the center of each classroom.


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