

## **An online course for freshmen? The evolution of a successful online CS1 course**

### **Prof. Frank Vahid, University of California, Riverside**

Frank Vahid is a Professor of Computer Science and Engineering at the Univ. of California, Riverside. His research interests include CS/engineering education, and embedded systems. He is a co-founder of zyBooks.com.

### **Joe Michael Allen, University of California, Riverside**

Joe Michael Allen is a Ph.D. student in Computer Science at the University of California, Riverside. His current research focuses on finding ways to improve CS education, specifically focusing on introductory programming courses known as CS1. Joe Michael is actively researching the impact of using a many small programs (MSP) teaching approach in CS1 courses. His other interests include educational games for building skills for college-level computer science and mathematics.

# An online course for freshmen? Features of a successful online CS1 course

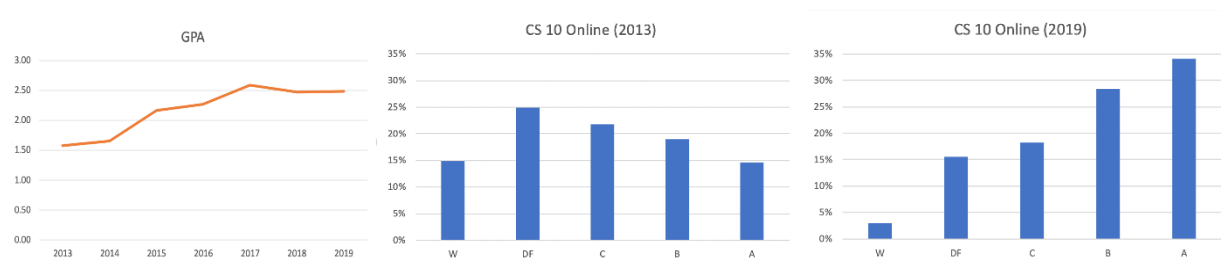
## Abstract

Online courses often have drawbacks for young college students that lead to low engagement and low success. We have taught an online CS1 section at a major university every quarter since 2013, and discovered features that have led the class to evolve to have high engagement and high success. Those features include: (1) synchronous meetings with instructors projecting video/audio and students actively participating via a text chat forum (2) strong learning content/tools outside class, (3) simple class structure and assigning many small tasks rather than a few large tasks, and (4) strong instructors. The online section's overall grade performance is now excellent, and the online section's end-of-quarter evaluations are also competitive with in-person, sometimes stronger, and commonly rate the class in the 80th percentile of all classes on campus. Students often express surprise at how engaging the online class was, with comments like "I've never been so engaged in a class; I wish more classes were online." The class has served as the model for online CS classes at other universities as well.

## Introduction

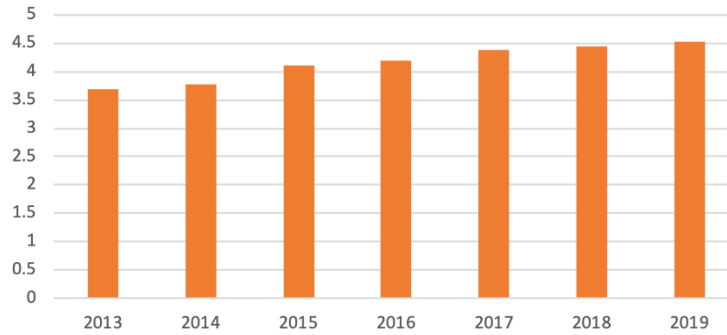
Online courses provide students potential benefits, like scheduling flexibility, time savings, and speed. Instructor benefits include flexibility, the ability to handle more courses or students, and time savings. But, online courses can have drawbacks, like low student engagement and success [1 - 3]. Such drawbacks may be pronounced for less disciplined students like college freshmen.

We have taught one online section of our Introduction to Computer Science course, or "CS1," quarterly since 2013, teaching the class 25+ times to over 1,000 students. Initially, the online section had a DFW rate (Ds, Fs, or Withdrawals) and evaluation scores lower than we desired, but has evolved to achieve excellent grades and evaluations, shown in Figures 1 and 2. This paper describes the key features that led to the course's success.



**Figure 1. Online CS1 grades have improved to grades above-average for a typical CS1.**

In 2013, we started teaching one online section each quarter. The main goal was to provide students the benefits of scheduling flexibility and time savings (e.g., no commuting). A second goal was to benefit students by allowing them to enroll even if our in-person sections were filled, since the online section had no room capacity restrictions. Additional goals included bringing in department revenue from students outside our university, and giving instructors more flexibility.



**Figure 2. Course evaluations have improved, resulting in typical rating of 4.5/5.0, which ranks the class among the most popular of all classes across campus.**

The online section usually covers the same content as the in-person sections, using the same textbook, homeworks, programming assignments, and exams. This "online CS1 section" typically has 75-100 students enrolled, taught by one instructor and one teaching assistant.

### **Synchronous lectures with active chat**

#### *Synchronous lectures*

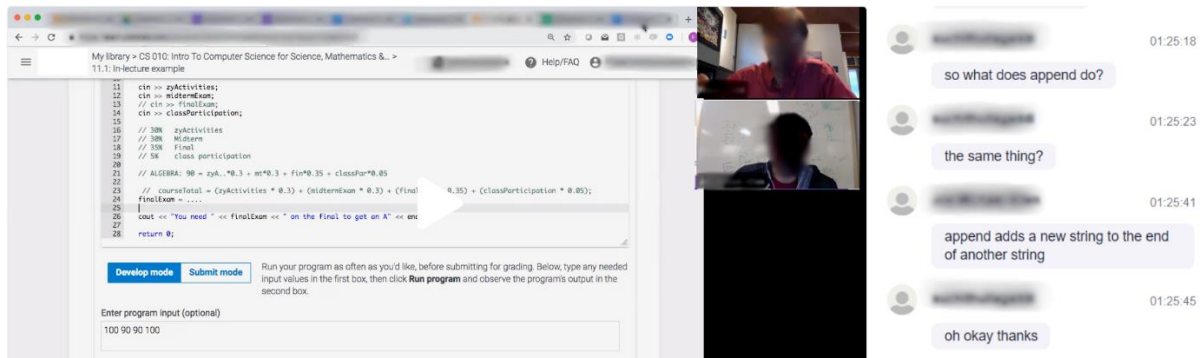
Our course in 2013 was asynchronous with respect to meeting times, with optional online discussions and office hours, to give students maximum flexibility. But we found many students were not completing work or attending any online sessions. In collaborating with instructors who had started online classes on campuses in our university system, a theme was evolving: "Students need to feel they are part of something."

Engaging students became a key focus, and we added more required synchronous meetings over the years, evolving 3 hours of lecture and 3 hours of lab, just like the in-person sections. We use Zoom for synchronous meetings. The instructor and possibly TA broadcast video/audio while doing a screen share, and students view video/audio but communicate by typing in Zoom's chat box. Recorded meetings (video/audio/chat-logs) are made available to students for reference or for students who miss an occasional meeting.

#### *Active lectures*

##### **Examples**

We run in-person lectures using "active learning." Students learn the basics before class (described later), so instructors spend lecture coding examples, consistent with research that shows that humans learn through examples [4-5]. We run online lectures similarly; the instructor shares their screen to display a coding window, and then codes examples throughout the lecture. Figure 3 shows our typical online class setup with the instructor teaching via screen share, the TA being online and active in answering questions, and the chat box on the side, open and active.



**Figure 3. Synchronous lecture: Students see and hear the instructor (and perhaps TA) and participate by typing in the chat box.**

### Polling/tasks

While working on examples, the instructor often polls the students, as in "What will this code output?," or "Now you code a loop that outputs 10 down to 1." In in-person lectures, polls may be a show of hands, or students solving a problem on paper alone or in groups of 2-3. Online, we use the chat box for students to submit their poll responses.

### Culture of mistakes

Online and in-person, we develop a "culture of mistakes." The instructor makes many mistakes while coding (often unintentionally), and also looks for mistakes in student-submitted code, praising mistakes as learning opportunities. This culture reduces student fear and encourages participation.

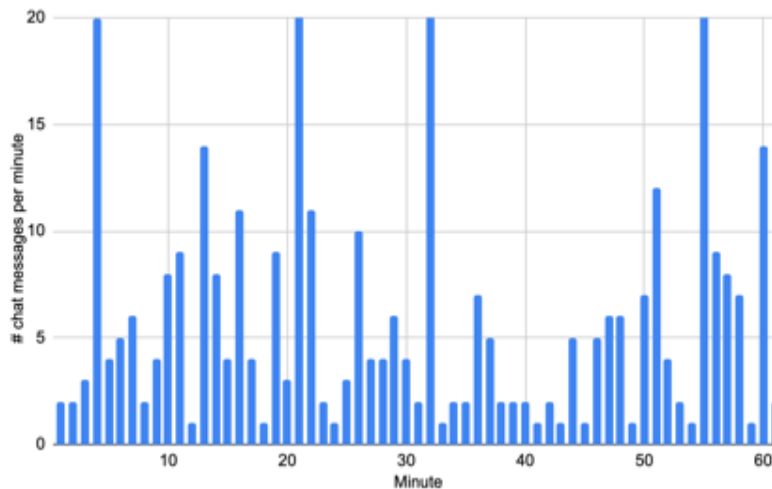
### Chat

To our surprise, the chat box has taken on tremendous importance and contributes greatly to the online section's success. The chat box:

- *Makes questions or comments easy.* Typing in the chat box is easier and less attention-getting than raising a hand in in-person lecture. Chat questions may be brief phrases like "Why void?" or comments like "I'm confused" or "Anyone else find vectors tough?" that students would never share in lecture.
- *Increased communication.* Online, students communicate more than in in-person lectures, answering each others' questions, encouraging each other, and making humorous comments. Before lecture, informal discussions occur. Names appear in the chat so are used by instructors and students, as in: "Nice catch Ally!", helping students feel more connected [6].
- *Quick polls.* The chat enables fast and thorough interactions. Instructors can ask a question and get responses from all students, even 100 students and even typed responses, in seconds.

A good discussion forum outside scheduled class time is also important. We've used Piazza, but are shifting towards Discord since today's students prefer its real-time communication. In about 5 weeks of class, we saw 628 Discord messages between students (in one general channel) compared with only 70 messages on Piazza (a majority of which were private messages to

instructors, or announcements from instructors). We've found that enabling students to actively communicate with one another is especially important for an online class so that the students can build a community [7].



**Figure 4. Bar chart showing chat messages/minute. Peaks are students responding to instructor questions; the figure caps the bars at 20 but several extended well above 20.**

### **Strong learning content outside class**

We focused on creating strong learning content for students outside of class. Textbooks have never been ideal for learning STEM subjects. Putting textbooks or video lectures online are the old paradigms in new technology; if the web is a superhighway, they are like horses on the highway. And, video is hard to maintain. The web's power is interactivity. Thus, we did not record videos, but instead created online interactive learning content with animations, learning questions, and auto-graded homework, plus some text and figures. One of our instructors even co-founded a company to build the content (zyBooks) [8], now used at 600+ universities and 600,000+ students (acquired by Wiley). Other online courses might use other commercial products, like Sapling Learning [9] for chemistry, or TheExpertTA [10] for physics, or invest in creating interactive learning content using a learning management system like Canvas [11], or create their own interactive learning system. Well-designed interactive learning content has been shown to cause students to actively engage with the content, especially when some course points (5-10% of total course points) for working through such content before scheduled lecture times.

### **Simple class structure and assigning many small tasks**

For all classes, but especially online, a simple class structure benefits students. Simple means:

- Few distinct tools/sites, all cloud-based: Every login or subscription can be a hurdle, student computing platforms vary greatly, and students lack technical support at home. In our CS1, the students have one cloud subscription for all their reading, homework, and programming assignments, with everything auto-graded, plus Zoom and Discord.

- Weekly repeating pattern: Keeping track of due dates, and scheduling work, is challenging for all students, especially online students. Our online learning content is configured by week, so every week is the same: That week's readings are due before lecture, homework by Sunday at 9 pm, and programming assignments by the next Tuesday at 9 pm.
- Many small tasks: CS1 classes traditionally assign one large programming assignment per week. We instead assign 5-10 smaller programs, all focused on that week's topic. The students get more practice and get started earlier since the smaller tasks are less intimidating. Plus, if stuck on one task, students can move on to another, thus reducing the students' need for help, which is especially important in online courses where help may be less available. And, students do better on exams, plus our analyses show students easily transition to a CS2 that uses one large programming assignment per week.

### Strong instructors

While explaining concepts is important, we believe that is just one part of an instructor's role. A strong instructor (or TA) must also:

- Connect: Making the student feel they are part of something, joining the students on a journey. Each instructor connects in different ways, combining different amounts of role modeling, encouragement, empathy, energy, humor, lucidity, excitement about the topic, etc. Connecting is the art part of teaching. Research shows the importance of "rapport" in online courses [12 - 13] in decreasing dropout and improving grades.
- Be authoritative: An instructor must run a class well, including designing appropriate course topics and policies, sharing the topics/policies in a clear/firm manner (but not authoritarian), and smoothly dealing with inevitable issues that arise (requests for late work, cheating, etc.) while staying positive and professional.

Of course, no school can rely on every teacher being strong. With a good course framework -- strong learning content outside class, example-based lectures with lots of polling, and a simple class structure and many small tasks -- then even an average instructor can step in and still see students have success and be satisfied.

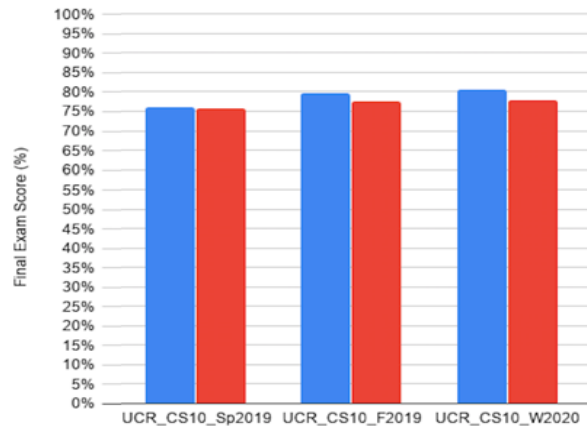
### Outcomes

Overall, students evaluate the course in the 80th percentile of all courses on campus, and they express very positive comments, as shown below. Negative comments are rare; the few non-positive comments say they already had programming experience, so the class was slow for them (which is OK). Typical evaluation comments include:

- "I found this class an **amazing experience** from all other classes I have ever took. The online format makes me less apprehensive to ask questions"
- "I strongly **recommend anyone to take this course online rather than in person!** Believe it or not, this was actually my **most interactive class** even though it was online!"
- "I don't think I had ever been **so excited to actually attend** a certain class ever."

- "Zybooks and this teaching method-- **learn at home and explained in class**-- made this course a wonderful experience."
- "...actively **engaged with students by asking them questions in the chat box** which is a strength of the online class"
- "The technique of using **many small labs** instead of a few large ones was singular in **keeping me focused and excited**"

Figures 1 and 2 showed the grade and evaluation outcomes. The online students perform competitively on the identical final exam given to all CS1 sections, shown in Figure 5.



**Figure 5. CS1 online sections perform about the same as the in-person sections on the final exam. Three recent quarters are shown, with red (right) bars being online. The small difference is due to most computing majors are scheduled to in-person sections (due to the college of engineering's learning communities).**

## Conclusions

While online courses are often considered inferior to in-person courses, our experience is that a well-run online course can yield strong grades and highly-positive student evaluations, with many students saying they actually prefer the online course due to its extensive engagement and interactivity. The key features of such a successful online course includes: (1) synchronous meetings with instructors broadcasting video/audio for live-coding of examples, with an actively-used chat box, (2) Strong learning content outside class, (3) simple class structure and assigning many small tasks instead of a few large ones, and (4) strong teachers who connect with students. We believe online courses should be incorporated into a university's course offerings so that students get a balance of in-person and online courses to reap the benefits of each, and so that departments better utilize classroom and teaching resources as well.

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