Strategies for Equitable Participation in an Introductory Computer Science Course*

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Abstract

In this paper we describe techniques intentionally designed to promote inclusivity and equity in an introduction to computer science course. We describe approaches for using randomly-drawn name cards as an alternative to cold-calling students for participation in class. We also discuss using an online polling technique that utilizes components of the Peer Instruction pedagogy to solicit low-stakes individual contributions. In each case, we motivate the "best practices" we have experienced and propose methods for making computer science classrooms more inclusive and equitable.

1 Introduction and Motivation

Computer Science is an incredibly influential discipline that provides an opportunity to develop technology to help solve both big and small problems in our world today. However, if the people developing the technology do not represent our communities or populations, then the solutions to the problems are unlikely to be representative, and as a consequence, will be limited in insights,

efficiency, effectiveness, and contain an unintentional bias [7] [6]. It is imperative that the classrooms where the foundations of CS education are introduced and established are welcoming and inclusive.

Efforts to include more women in computer science have been ongoing for decades [6, 1] [5,11]. While progress has been made, there is still a significant disparity in gender (77.7% male vs. 22.3% female) and ethnicity (39.8% white, 27.3% Asian, 15.6% Nonresident Alien, 9.6% Hispanic, 3.9% Black or African-American) of Bachelor's degrees awarded in Computer Science, Computer Engineering, or Information [1] [11]. Diversity in computer science is important. A diverse workforce that is representative of the people using technology is essential for solving hard problems that require perspective, creativity, and contributions from many. Furthermore, there is a tremendous demand for more computing professionals, and the industry cannot afford to be exclusive.

Many strategies have been shown to be effective in increasing the equity and inclusion of underrepresented students in computer science focused in the introductory (CS 1) course. These strategies include making the introductory course more welcoming [10] [8] and less intimidating [2, 8] [1, 9], making the assignments more meaningful [4, 11] [3, 10], building peer-tutoring pipelines [5] [4], and separating experienced CS 1 students from inexperienced CS 1 students to reduce intimidation, fear and imposter syndrome in novice students [3] [2].

In an effort to achieve inclusion and equity in the classroom, we would like to provide an environment where each student is not only provided with equal opportunities, but where each student is motivated to participate equally and each student feels like they belong in the computer science classroom. Our goal is to provide a classroom environment where every student knows each other, is known by others, and is both supported and supportive in achieving common goals of learning, developing foundational knowledge, and building meaningful software.

In order to create an environment of belonging in which students feel invited, equal, and included, we feel we need to be rigorously intentional regarding the following:

- Students feel safe to participate in the classroom
- Students do not feel ignored, neglected or left behind
- If a student is falling behind, there is a proactive approach of identifying them and reaching out and assessing what additional resources may be needed

Towards this end, we describe two different approaches we have adopted in CS 1 that are designed to promote inclusion and equity, and provide a scaffold for early identification of struggling students. The first approach describes the use of cards with each student's names on them which are used to help

ensure every student in the class has an equal opportunity to contribute. The second approach is an adapted format of Peer Instruction using PollEverywhere (`https://www.polleverywhere.com/`) to motivate all students to participate and provides an assessment mechanism that can provide early detection for struggling students.

2 Participation Cards

One of the most difficult tasks for a professor is to present course material at an appropriate pace for the students taking the course. When asking a question of the class, it is often convenient to call upon the same small group of students – generally those who sit in the front, have raised their hands, and are making eye contact – to answer the question and move the presentation of the material along at a desired pace. Unfortunately, the approach of habitually calling on the most attentive students will not get a reasonable measure of how the average (or struggling) student is following the presentation or understanding the material. One possible solution to this challenge is to randomly cold-call on students. However, this practice can create a stressful and anxiety-inducing environment in which students feel pressured to always be "on" and could feel discriminated against or "picked-on" by the professor, causing a lack of trust with the professor and a lack of comfort in the classroom. As an alternative, we have found success in creating an inclusive environment by using a deck of cards in which students have written their name.

2.1 Implementation

At the beginning of the semester, a deck of blank cards (either index cards or blank playing cards) can be distributed to the students. Each student writes their name on the card with any helpful phonetic spelling as needed (or other relevant information: year, major, etc). This deck of cards is then used throughout the class when a question is poised by the professor. The top card is drawn, the student is called upon, then the card is discarded or placed at the bottom of the deck.

We found that being explicit about the "why" of using the cards – explaining that they are a tool to invite more equity into the classroom – is an important key to reducing the anxiety around having students' names called out. We also found that it is also important to take extra care in explaining to the students that the goal is for all to learn, and that there is absolutely no shame in saying "pass", "I don't know", "can you repeat the question", or even using a life-line by asking the the next card to be drawn for another student to help in answering the question.

In practice, we have found it best to shuffle the cards, draw the top card, and have the corresponding student be the "card bearer" for the rest of the class period. Thus, when a question is posed to the class, the "card bearer" student takes the top card and announces the student who will have the first opportunity to respond. This helps take the burden off of the professor of being the "bad guy" and also helps all of the students get to know each other better in the class. Having students say each other's names, and look around the room to make eye-contact with the person whose name they just said is a great way to give students an incentive towards getting to know who is in their class. This worked particularly well for our use case with relatively small classes (30 students).

Creative uses of these cards include using them to take attendance by going through the deck, calling students names and separating into "present" and "absent" piles, dealing out cards to create groups, as well as using them to create a random seating chart. In future classes, we plan to add an element of gamification by adding a few "reverse" cards where the professor will answer their own question, as well as a "draw two" card where the question is posted to the next two students selected in the deck who can then collaborate to produce an answer.

2.2 Advantages

Using this approach has several advantages. Students know it is fair (and equitable). Students know that being called upon isn't done out of a professor's spite but just the "luck of the draw." Our goal is to create an atmosphere where students adopt the attitude of "we are here to learn together." The cards help provide an inclusive practice and establish more equity as each student has an equal chance of being called upon.

Student feedback on Participation Cards (included with their permission):

- "I appreciated them because I hate sitting through the long silence after a question is asked and only a handful of us are willing to speak up."
- "I liked that they gave students an option to pass, but also gave students a chance to answer questions without having to raise their hands and speak (which can be anxiety inducing)"
- "It gives everyone a chance to participate in class"
- "The class environment was really supportive of each other, I think that volunteering an answer was encouraged. I think that the cards with our names on them could've been used more"
- "It helped keep the class engaged and I thought they were good."

3 A Modified Approach to Peer Instruction

Peer Instruction is a well-documented pedagogical method that first asks students to individually respond to a multiple-choice-question posed in a classroom [9] [7]. After the initial question, students discuss in small groups, challenging each other to develop a consensus. Afterwards, the students answer the question again, oftentimes with improved results. Peer Instruction has been documented to be an effective approach to increase student performance on conceptual questions [9] [7]. An advantage of Peer Instruction is that it provides an opportunity for all students to participate simultaneously. As such, Peer Instruction helps prevent the non-equity practice of professors asking questions of the class and regularly calling on the same students or only students with raised hands.

Peer Instruction has many advantages; however, challenges in finding the right kinds of conceptual questions (one where not everyone initially agrees) and balancing the Peer Instruction pedagogy along with content delivery has motivated us to adopt a modified Peer Instruction approach to the CS 1 classroom. We believe this approach has been effective in the goal of making the classroom more inclusive and equitable.

3.1 Implementation

As an alternative to a hand-held "clicker" device that students would have to purchase, we require students to purchase a $15 semester subscription to PollEverywhere, which allows them to use their smartphones and computers to participate in the classroom Peer Instruction activities. The subscription also allows us to retain students' answers over the semester. While there is an option to poll students anonymously, we found it advantageous to utilize questions which attached the student's name to their response. The answers displayed in class never had any identifiable information; however, the professor could identify students' answers afterwards through the PollEverywhere account. One of the significant advantages to this method is that we can track attendance and participation.

In the standard Peer Instruction approach, students would collaborate after answering the question individually. In practice, we found that it could be redundant to have students complete the collaboration portion if the class was in agreement with their original answers. The collaboration component was most valuable when there was not a strong consensus in the initial vote. PollEverywhere provides the ability to display the results as they are entered or after all results have been submitted. Thus, if there was a strong consensus, it made the most sense to show the results and reinforce the correct answer with an explanation. However, if the students' answers were distributed across the different

options, the option to utilize the traditional Peer Instruction methodology by having students share their answers with their peers to see if they could come to a consensus was effective. This modified Peer Instruction approach is depicted in Figure 1.

We chose to use the answers in a low-stakes fashion where participation received full credit, regardless of correct or incorrect submissions. We feel that normalizing errors in CS 1 classes can help students not to get discouraged when they encounter bugs in their programs. Furthermore, when explaining this choice of low-stakes participation to students, we also took an opportunity to discuss the importance of having a growth mindset when learning computer science as well as reiterating that we are all in this classroom to learn and that one of the most effective ways to learn is to make mistakes.

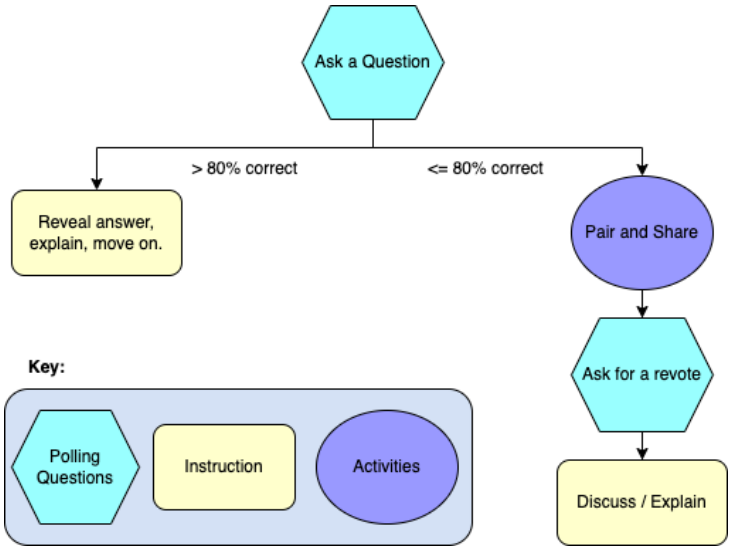

Figure 1: Flowchart for adapted Peer Instruction approach. Note that 80% accuracy is an estimate, and in practice, this threshold is malleable.

At a high-level, a typical class would begin with a low-stakes attendance question to get students responding and stimulate conversation (see table 1). We then briefly review the previous lecture's concepts and conduct a PollEverywhere review question. Next, we introduce new material, and then provide the students with a hands-on activity to practice the new topic. Once the students have had a chance to try out the new concept, we conduct another polling question using the modified Peer Instruction methodology. Finally, at the end of class, we ask students to reflect on how they feel about what they

have learned.

3.1.1 Attendance Questions

The attendance questions provide conversation starters for community building to take place in the few minutes before class has started. For most of these questions, we found having the answers displayed as they came in was a nice way for students to build off of each other's answers as well as start conversations. We begin a class with a simple, ice-breaker question that is primarily intended for attendance purposes. The goal of the attendance question is to set a non-threatening participation pool to facilitate participation throughout the class period.

Table 1: Example Attendance Questions

What's your favorite animal?
If you had a theme song, what would it be?
What is your favorite food?
What is your favorite hobby?
What was something that made you smile this weekend?
When you were a kid, what did you want to be when you grew up?
How are things going on Assignment 4?
Were you able to complete Lab 2?

Sometimes these attendance questions played a more administrative role – serving as a way to get a feel for how students were progressing with coursework. Questions like the examples in the last two bottom rows of Table 1 were effective in assessing how an assignment or lab was going for students. This also presents an opportunity for a follow-up question to help identify where students may be stumped.

3.1.2 Review Questions

After answering the attendance question(s), we would then move into a quick review of the material covered in the previous class session and provide an opportunity for students to test their understanding of the previous material with a review question. The review question provided an opportunity to assess students' understanding of the previous material and often facilitated conversations clarifying any misconceptions about the previous class's material.

3.1.3 New Concept Questions

We next would move on to introducing new concepts. Throughout the classroom session, we typically introduce a topic, provide examples, then give a short individual or small group exercise to give students an opportunity to practice the new concept in the class on their laptops computers. After the exercise is an opportune time for another polling question to reinforce the concept introduced.

3.1.4 Reflection Questions

At the end of the class period, we give a final poll asking students how they felt about their understanding of the material presented in the course using the 'clickable image' question type in PollEverywhere, as represented in Figure 2. This allowed students to rate, on a visual continuum, how confident they felt about the concepts talked about in class.

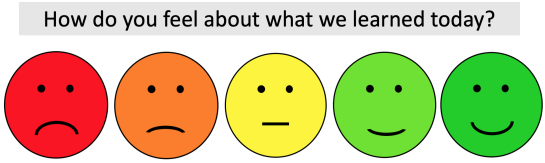

Figure 2: A representation of a "clickable image" question that was used to encourage students to reflect on what they learned.

Looking at answers from the reflection question after class can provide immediate feedback as to how a class period was received by students, as well as note students who may benefit from an individual contact and invitation to stop by office hours to discuss any difficulties. In our experience, this timely and proactive engagement can be instrumental in preventing a student who happens to be struggling with a particular concept from falling significantly behind in the course content. We feel this engagement can also facilitate and encourage future interactions with a struggling student and the professor. Finally, this end-of-class reflection question requires the student to actively reflect on their understanding of the material, which can also provide the impetus for them to request additional help on a topic that may not have made sense during the class period.

3.2 Advantages

We feel that the advantages of using a modified Peer Instruction approach are numerous. First, it builds equity in the classroom as the multiple choice polling

questions allow every student to have an input into the class.

The results from the surveys give professors an immediate metric as to the overall understanding of a topic. This is in contrast to a general "feel" for the understanding obtained by a professor reading the expressions of students in the classroom.

The PollEverywhere results allow us to track the responses for each student. Thus, a student's absence can be detected by the system and a proactive reach out (e.g. email, text message, or message to academic support staff) could be helpful in preventing them from falling behind. A dashboard from the results of the polls can be easily created to give more information about the overall health of the students in the course.

Lastly, the polling system keeps track of each student. Thus, it works well in small courses, but the effectiveness is not dependent on the number of students in the course as the polling software scales to larger classes.

Student Feedback on the use of PollEverywhere (included with their permission):

- "The [PollEverywhere] questions helped me understand the material we were covering while giving me examples/problems to think about and work through."
- "I felt like it kept me very engaged. It was a nice way to test my learning without being put on the spot."
- "PollEverywhere helped me to actually apply concepts and it helped me a lot in studying for exams!"
- "There were many ways it was used and it was a good way to see how people were doing and if there is anything that's not understood"
- "It is an easier way to practice questions in class"

4 Conclusion

Computer science is in high demand and is poised to help solve many different kinds of problems. The future of computing will be shaped by those people that feel welcomed into the discipline. Instructors in CS 1 courses have the potential to create environments that will foster a diverse and equitable learning environment that maximize the potential of individual students and increase the diversity of students that contribute to developing technology. In this paper we described techniques intentionally designed to promote inclusivity and equity employed in an introduction to computer science course. These include an approach for using randomly-drawn name cards as an alternative to cold-calling students for participation in class and using an online polling technique that utilizes components of the Peer Instruction pedagogy to solicit low-stakes individual contributions. It is our hope that adopting practices

like this will create a welcoming, inclusive classroom environment and help all students learn computer science.

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