Assessing Community College Biology Student Perceptions of Being Called on in Class

Stacy M. Alvares,[†#*] J. Gwen Shlichta,[‡#] Jenny L. McFarland,[§] and Elli J. Theobald[¶*]
[†]Science Division, Bellevue College, Bellevue, WA 98007; [‡]Biology Department, Edmonds College, Lynnwood, WA 98036; [§]Biology Department, Edmonds College, Lynnwood, WA 98036; [¶]Department of Biology, University of Washington, Seattle, WA 98195

ABSTRACT

Random call has been proposed as an inclusive and equitable practice that engages students in learning. However, this inclusion may come with a cost. In some contexts, students experience anxiety and distress when being called on. Recently, focus has shifted to critical components of random call that may mitigate this cost. We examined how community college (CC) students perceive being called on by addressing 1) benefits that help their learning and 2) characterizing the anxiety students experience through this practice. To do this, we surveyed students in six biology courses taught by six faculty members over six academic quarters. We analyzed survey responses from 383 unique students (520 total responses) using mixed methods. Qualitative responses were coded and consensus codes revealed that students saw benefits to being called on, including paying attention and coming prepared. Qualitative codes also revealed different types of anxiety, both distress and eustress. Analysis of Likert scale survey data revealed perceptions of increased student interaction with their peers in warm random call classes. Furthermore, warm random call may increase participation in class discussions, and it is not correlated with increased extreme anxiety. These data suggest warm random call used in smaller, community college classes, may contribute to students' positive perceptions of being called on.

INTRODUCTION

Calling on students in the classroom is an active learning method that may promote student engagement, increase student preparation for class, diversify student participation, and allow instructors to assess student understanding and comprehension of concepts. Creating an environment in the classroom in which any student may be called on to share information and ideas may promote student engagement and encourage broader student participation in the classroom (Tanner, 2013; Waugh and Andrews, 2020; Metzger and Via, 2022). Data support the hypothesis that classes with higher student participation had higher grades on average (Gasiewski *et al.,* 2012; Eddy *et al.*, 2015). Generally, calling on students is associated with multiple dimensions of engagement, including emotional, behavioral, cognitive, and agentic engagement. In most studies, engagement measures fall into the dimension of behavioral engagement, which mainly include students participating in academic tasks that promote their own learning (Sinatra *et al.*, 2015). Additionally, some research indicates that students are often more prepared for class when they understand they may be asked to contribute to discussion (Gross *et al.,* 2015; Huseby, 2022). Further, Novak *et al.,* (1999) found that calling on students provides faculty with regular feedback from students, allowing them to assess depth of students' progress toward learning goals. Thus, class discussions that include the ideas of a range of students can benefit both students and instructors because it allows instructors to make real-time adjustments in their teaching or curriculum (Novak *et al.,* 1999).

Kimberly Tanner, *Monitoring Editor*
Submitted May 2, 2023; Revised Aug 30, 2023; Accepted Sep 22, 2023
CBE Life Sci Educ December 1, 2023 22:ar51
DOI:10.1187/cbe.23-05-0068

[#]These authors contributed equally and are the co-first authors.
*Address correspondence to: Stacy M. Alvares (stacy.alvares@bellevuecollege.edu); Elli Theobald (ellij@uw.edu).

There are several strategies instructors employ when calling on students. For the purposes of clarity, our definitions are as follows: Volunteer call is when an instructor poses a question, students raise their hands to volunteer to be called on to answer the question, and the instructor calls on an individual volunteer to respond. On the other hand, Chorus call is when instructors pose a question to the whole class and all students call out answers without being selected by the instructor.

Random call (RC) is a specific practice of calling on individual students who have not volunteered (Eddy *et al.,* 2015; Hood *et al.,* 2021). The mechanics of selecting those students for RC has been described in a variety of ways including, but not limited to, selecting a number at random that corresponds to an individual or group of students and asking them to share their thinking with the class (Knight *et al.,* 2016), using notecards for participation (Broeckelman-Post *et al.,* 2016, Tanner, 2013), or using a randomized list of student names, a deck of cards, or a cup of popsicle sticks (Pella-Donnelly, 2009; Tanner, 2011). RC can be conducted through sampling with or without replacement, and selects an individual or group: in Group random call, instructors pose a question and randomly select a group to respond whereas an individual is randomly selected by the instructor during Individual random call. Regardless of how exactly students are selected, the two unifying threads of RC are 1) instructors select which students are called on as opposed to students volunteering and 2) instructors have some mechanism to ensure that all students have an equal opportunity to be called on. As a result, RC, as opposed to volunteer call, has the potential to engage and increase participation of all students compared with only calling on students who volunteer (Dallimore *et al.*, 2019). For example, a study on group RC suggested that students engage more with their group, leading to exchanges of reasoning and articulation of thoughts which positively impact student learning (Knight *et al.*, 2016).

Beyond logistics of how students are randomly selected, RC can sometimes be conflated with what some call cold call (e.g., EdComm, 2017; Cooper *et al.,* 2018). Cold call is when students are called on directly after a question has been posed without having a chance to discuss the question with their peers. On the other hand, Warm random call is when students are called on after they have had a chance to think and discuss the question with their peers (a.k.a. think-pair-share). In practice, an individual instructor may use warm RC, random cold call, or both. Our study focuses on the use of warm random call (warm RC).

Using RC (both warm and cold) has been proposed as a strategy to address opportunity gaps in the college classroom, specifically by providing all students equal opportunity for their voices to be heard (Metzger and Via, 2022). Researchers have demonstrated that using RC in a classroom reduces disparities associated with who shares their thinking with the class (Martin *et al.,* 2006; Eddy *et al.,* 2014; Dallimore *et al.*, 2019). In addition, in a class that relies on volunteer call, data suggest there is a discrepancy between who is speaking in the classroom and the actual diversity of students in the classroom (Eddy *et al.,* 2014). Further, students often associate higher academic performance of their peers with those students that speak the most in the classroom (Grunspan *et al.,* 2016). Therefore, the academic performance of students that do not volunteer to speak is often underestimated by their peers. This can not only undermine student confidence but can influence peer perception on mastery of a subject and reinforce gender bias (Grunspan *et al.,* 2016). A more structured classroom that includes RC may help in closing the opportunity gap for women, first-generation, and Black students (Eddy *et al.,* 2014; Eddy and Hogan, 2014; Dallimore *et al.*, 2019). Overall, calling on students in the classroom with RC has been recommended as a strategy to increase the inclusion of all voices in the classroom, provide for more diverse and equitable participation, and to support student learning (Tanner, 2013; Dallimore *et al.*, 2019; Waugh and Andrews, 2020; Metzger and Via, 2022).

Although the benefits of RC have been demonstrated in the literature, instructors may avoid using RC, or calling on students all together, to avoid alienating students and/or inducing unnecessary anxiety that interferes with student learning (EdComm, 2017, Cooper *et al.*, 2021). In a study where students were recruited from two large college biology courses that implement various active learning practices, 60% of the students interviewed in the study reported that cold call/RC increased their anxiety (Cooper *et al.*, 2018). Studies have also examined student anxiety associated with active learning practices. The fear of negative evaluation in social settings, both by peers and the instructor, was identified as the main source of anxiety (England *et al.*, 2017; Downing *et al.*, 2020). In addition, the thought of getting called on in class also led some students in large college biology courses to state that they would skip class due to their anxiety (Cooper *et al.*, 2018). Some students suggested that smaller class size, like the ones found in community colleges, might be a way to alleviate this anxiety (Cooper *et al.*, 2018). Moreover, although the fear of negative evaluation around active learning practices is still found in community college students, some community college students suggested that practices associated with warm RC may be a way to alleviate some of the anxiety (Downing *et al*., 2020).

Many instructors are aware of the benefits (greater diversity of student voices) and costs (increased anxiety) of RC (Waugh and Andrews, 2020). As a result, some instructors have reported practices of preparing for and enacting RC in ways that decrease the distress students may feel from getting called on while retaining the benefits of this inclusive practice promoting student engagement (Waugh and Andrews, 2020, Downing *et al.*, 2020; Huseby, 2022; Metzger and Via, 2022). Others have challenged the practice of calling on students and suggested that perhaps instructors reconsider how to hear and share student voices and if it is even necessary (Cooper *et al.*, 2021). However, previous work seldom cites studies of community college instructors or students when drawing these conclusions (Downing *et al.*, 2020 is a rare exception). While there are differences among the hundreds of community colleges, most have relatively small class sizes (less than 50 students) and more student opportunities for students to interact with faculty (via the classroom, teaching labs and frequent office hours). Community colleges are open access and tend to attract students who live locally, commute, and have extensive nonacademic time commitments with family and work (Freeman *et al.*, 2020). While small class sizes may contribute to alleviating anxiety, all instructors have the opportunity to use the critical components that Waugh and Andrews (2020) as well as Downing *et al.* (2020) identified as mitigating negative student

anxiety associated with RC and to be creative so as to better meet the needs of the students in their own class (Cooper *et al.*, 2021; Metzger and Via, 2022).

Finally, student anxiety during active learning practices is complex. It is important to examine both the presence of anxiety as well as the types and levels of anxiety students have in order to better understand the costs and benefits associated with a specific practice. For example, while getting called on in class can promote anxiety associated with negative evaluation in community college students (Downing *et al.*, 2020), a small increase in communication anxiety was also associated with increased student performance measured by final grade in a course (England *et al.,* 2019). Instructors in professions that often have high stress as part of the job also recognize that stress should be further described in a distress/eustress framework. Rudland *et al.* (2020) used this framework to describe a "hypothetical learning journey" in a diagram we modified to apply to RC in the classroom (Figure 1). In brief, stress is important for learning and stress-related growth. Therefore, some stress is good. Distress is a negative effect resulting from stress (Rudland *et al*., 2020), while eustress is defined as a positive form of stress that yields beneficial outcomes including increased attention and motivation that may promote learning (Rudland *et al.,* 2020). The important aspect of eustress is that it is moderate, short-term, and it is within a normal range of one's coping abilities. This idea has been further echoed by a RC instructor in research done by Waugh and Andrews (2020), who stated "So very large stresses are bad, even traumatic or life-destroying. But many small stresses can be productive…. I see RC as one of those little stresses; you can grow from this."

Research Questions

In this study, we investigate how students in community college biology courses experienced being called on in class and if being called on disproportionately affected students from minoritized groups. Specifically, we explored student reactions to consistent implementation of warm RC in terms of student participation–both personal and perceived–student engagement, motivation, and a sense of belonging in biology courses as measured by a students' perception of community and their comfort asking questions in class, and disaggregated responses by student demographics. To address how calling on biology students may impact student learning, we asked students in our biology courses about the benefits and interferences to their learning when they are called on and specifically addressed if warm RC would increase their anxiety and result in them avoiding attending class. Our specific research questions were:

1. How do students experience classes that use warm RC compared with classes that do not use RC? (RQ1; answered with six forced choice survey items)
2. What benefits do students perceive from getting called on in class? (RQ2; answered with one open-ended question: In what ways did being called on in class support your learning?)
3. What interferences do students perceive from getting called on in class? (RQ3; answered with one open-ended question: In what ways did being called on in class interfere with your learning?)

METHODS

Context and Participants

This study took place at Edmonds College, a 2-year community college in a suburb of Seattle, Washington, over six academic quarters from Spring 2018 to Winter 2020. The last two weeks of Winter quarter 2020, were moved online due to the start of the pandemic. These two weeks included a week of final exams, so this disruption likely had little impact on data collection in that quarter. Students were surveyed in six biology courses: the 3-quarter Majors Biology series (BIOL& 211, 212, 213), the 2-quarter Human Anatomy & Physiology sequence (BIOL& 241, 242) and Microbiology (BIOL& 260). During the period of this study, these courses were taught by eight different instructors. All instructors in this study used the same set of slides at the start of each quarter to explain the purpose of calling on students and to describe the different ways students will be called on in class (see Supplemental Appendix C). While the initial introduction of calling on students was consistent, this approach did not control for additional forms of instructor talk that may impact students' experiences in class (Seidel *et al.*, 2015, Harrison *et al.*, 2019).

We categorized each classroom as either using warm RC or not using RC (Not RC). In classes that used warm RC, each instructor had students fill out an index card with their name, pronouns, and additional information that varied by instructor. Then the instructor shuffled the deck and used these name cards to randomly call on students each class period. In this study, RC instructors used warm RC which, as described earlier, entails posing

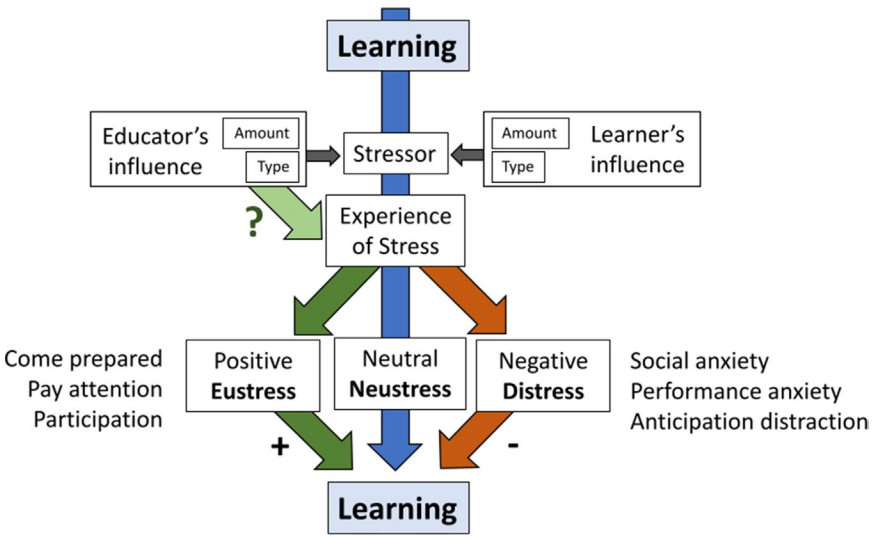

FIGURE 1. Effect of stress on learning: positive stress, or eustress, can positively impact learning and distress can negatively impact learning. This Figure was modified from Rudland *et al.* (2020).

a question and allowing students to discuss it with a partner or small groups before an individual student is called on to share out as a group. Once the student was called on, the card was moved to the back of the deck (i.e., sampled without replacement). Instructors went through the entire deck and a specific student was not called upon again until each student had been called on once. After the instructor had called on each student in the deck, the deck of name cards was reshuffled. Students who were absent on the day they were called on were put back into the deck. Lectures were 2-h blocks twice a week with fewer than 50 students per class. On average instructors called on at least 50% of the students within one class period, which means that all students were called on within one week (i.e., 2 class periods).

In our study, when we use the term RC, we are referring to classes that use warm RC (not cold call) and we are comparing student outcomes when students have been in classes that use warm RC versus classes that do not use RC. In our study, at the start of each quarter, instructors in each of the courses included here explained the definitions for different types of calling on students that are used and which type of call would be used in their classroom.

In classes that we categorized as Not RC, two different types of volunteer call were used: individual and group volunteer call. Individual volunteer call occurs when an instructor poses a question to the group and only calls upon a single student who voluntarily raised their hand to answer the question. Group volunteer call, which we referred to as "chorus call," occurs when the instructor poses a question to the class and students all call out their response without being directly called upon by the instructor. In classes that did not use RC, instructors reported that they used either individual or group volunteer call daily.

To be clear, in this study, we are comparing student experiences in classes that use RC and student experiences in classes that with (Not RC). We will use these abbreviations and capitalizations throughout the paper (in text, figures, and tables) to refer to these two types of classes. This will be written as simply RC and Not RC classes for concision and clarity. We acknowledge that the patterns we see may be additionally influenced by other things that are happening in the class. We tried to control some of these through our survey design and data analysis, as we describe below, but acknowledge that it is not possible to control for all aspects of the classroom experience.

Survey design and implementation

We developed a survey (authors S.A. and J.M. in 2018), to address our three research questions. Specifically, we asked students questions relating to their experiences with being called on in class. These questions were answered in ways that we then analyzed with qualitative or quantitative methods. The strength of this mixed-methods design is that we can better triangulate students' experiences and to provide additional context to students' quantitative responses.

Cooper *et al.* (2018) reported that cold call/RC substantially increased student anxiety in large enrollment biology courses at a research-intensive university. Their interview data suggested a harmful effect of calling on students, including skipping class and high anxiety that students reported interfered with their learning in class. The results of that study led us to create the options for multiple-choice question 12 in our survey: "Which of the following statements best describes your state of anxiety or comfort at the end of your current biology class?" We wanted to know if our students had similar perceptions as those interviewed in Cooper *et al.* (2018) to our practice of warm RC, in particular if they would skip class or be unable to learn because of increased anxiety.

We gathered feedback on the survey design–question construction and clarity–as well as our sampling plan at two CC Bio INSITES workshops in 2018 and 2019. This feedback primarily came from community college faculty who teach at colleges across the United States, and we used it to revise the questions and our approach. Additional questions to triangulate students' complicated emotions and behaviors as well as further validity evidence (e.g., face validity, etc.) would have helped the robustness of the survey, but such evidence was not collected (see Limitations and Future Research below). Thus, we must take student responses at face value. The survey, in its entirety can be found in the Supplemental Materials (Appendix A) and is summarized in Table 1.

To answer our first question (RQ1), we surveyed students using a 6-question online survey. Students could only select one of the answers provided (Table 1) and were assumed to select the best answer that most accurately represents their personal experience. We disaggregated student responses based on demographic identity to understand if there were differential experiences between students in classes that used warm RC or that did not use RC.

In addition to these six multiple choice questions, we also asked students two open-ended questions: "In what ways did being called on in class support your learning?" and "In what ways did being called on in class interfere with your learning?" We did not give guidance to students on the various ways being called on may "support" or "interfere" with learning. It is possible that students had different definitions of these terms in mind when answering these questions. For this reason, we took responses at face value. We coded student responses to these open-ended questions using a conventional content analysis approach (Hsieh and Shannon, 2005) along with thematic coding (Erlingsson and Brysiewicz, 2017; Kleinheksel *et al.,* 2020). Table 1 summarizes all the questions that we asked students; the final version of the survey is available in Supplemental Appendix A.

The survey was implemented in all 200-level biology classes at Edmonds College. Implementation was relatively consistent in each of the classes: Students had between 5 and 7 days to answer the questions and upon completion, students were awarded a small number of extra credit points for completion. The survey was administered through the online course management system and instructors reminded students at least twice to complete it. Supplemental Table S1 shows the number of total responses and the associated Chi-squared analyses testing the hypothesis that the distribution of students by demographic identity in the warm RC and Not RC classes was the same.

In total, data were collected in seven quarters (Fall 2018–Winter 2020) from six biology courses, taught by eight instructors. Four of the courses were only taught by a single instructor (three used warm RC, one did not), one course was taught by three instructors (one used warm RC, two did not), and one course was taught by four instructors (two each used

TABLE 1. Questions asked to students and the possible responses

Research question	Survey question abbreviation	Student survey question	Possible survey response(s) questions were forced choice, if not open-ended
RQ1: How do students experience classes that use warm RC compared with classes that use non-RC?	I Participate	I participate in discussion with other students in this class. (single response)	5-point Likert scale: Strongly Disagree to Strongly Agree
	Percent Answer	In a typical week approximately what percentage of students answered questions in your class over this quarter? (single response)	0–25% 26–50% 51–75% 76–100%
	Motivated	I was motivated to try hard on course assignments and exams in this class. (single response)	5-point Likert scale: Strongly Disagree to Strongly Agree
	Community	I feel like I am part of a community of students in this Biology class at EdCC. (single response)	5-point Likert scale: Strongly Disagree to Strongly Agree
	Comfort Asking	I felt comfortable asking questions in this class. (single response)	5-point Likert scale: Strongly Disagree to Strongly Agree
	Anticipate	If I anticipate being called on in class, I am likely to…(single response)	Participate without worries Be engaged and somewhat anxious Be nervous until I am called on Be highly anxious such that it will interfere with my classwork. Skip class to avoid speaking in class
RQ2: What benefits do students perceive from getting called on in class?	Benefit	In what ways did being called on in class support your learning?	Open-ended response
RQ3: What interferences do students perceive from getting called on in class?	Interfere	In what ways did being called on in class interfere with your learning?	Open-ended response
Demographic questions asked on the survey			
Question	**Abbreviation**	**Possible responses**	
What is your gender?	Binary Gender (updated for manuscript to report Men vs. Women; no other responses were made)	Female; Male; Trans; Gender Nonconforming/Other; Prefer not to respond (single response)	
I identify my race or ethnicity as	Combined to compare PEER vs. non-PEER	African American/Black; Asian/Asian American; Caucasian/White; Hispanic/Latinpo/Latinx; I prefer not to answer; Native American/American Indian/Alaska Native; Pacific Islander (single response)	
Is English your first language?	English as First Language	Yes; No (single response)	
Are you a first-generation college student?	First Generation	Yes; No (single response)	
Are you working while going to school?	Combined to compare students who work more than half time (20+ hours) vs. students who work less than half time (<20 h)	No; Yes, 10–19 h per week; Yes, 20–29 h per week; Yes, 30–39 h per week Yes, 40 or more hours per week; Yes, Under 10 h per week (single response)	

either warm RC or Not RC). The survey was completed by 383 unique students (respondents), which totaled 520 survey responses (some students took the survey multiple times, either in multiple quarters, or in multiple courses). Of this set, 286 responses were completed in warm RC classes (four instructors) and 234 responses were from students in Not RC

classes (four instructors). The average class size in the sample was 24 students and ranged between 9 and 49 students. Beyond the inherent strength of sampling hundreds of community college students, one unique strength of this dataset is that our sample comprised multiple instructors that used warm RC and multiple instructors that did not use RC (note that no instructor used both call types).

This research was approved by the Edmonds College (EC, previously known as Edmonds Community College) Institutional Review Board (IRB) and was deemed exempt because these data were collected in a typical educational setting and involved normal educational practices that were likely to improve the quality of the course and were not likely to adversely impact students. The survey included confidentiality and informed consent information approved by the EC IRB (see the beginning of the survey in Appendix A). The data from students under 18 were removed from the data set and the remaining data were deidentified and analyzed after grades for these courses were submitted.

Disaggregating by student demographics

After the first five quarters of data collection, six questions were added to the end of the survey to gather demographic information from students. These questions were included to assess the possibility of differential experiences of students in classes that used different call types. The subset of data with student demographic information (a.k.a. "subsetted data") included only two quarters and was from six instructors who taught four different courses (BIOL& 211, BIOL& 212, BIOL& 241, and BIOL& 260; note that the & is included in the course number as reference to Washington State Community Colleges common course numbers) and resulted in 156 student responses from 132 unique students. Two of these instructors used warm RC (83 students) and the other four instructors did not use RC in their classes (73 students). Students were more or less evenly distributed across classes that used warm RC and those which did not by demographics (Supplemental Table S1), with the exception that in classes that used warm RC there were more students who reported learning a language other than English as their first language. As we explain below, this is unlikely to impact our results.

We disaggregated data by race and ethnicity: students who identified as PEER (persons excluded because of ethnicity or race - students who identify as African American of Black (31), Hispanic, Latino or Latinx (9), Native American, American Indian or Alaska Native (1), or Pacific Islander (7) (Asai, 2020); White, Asian, and Asian American students were combined into a single non-PEER group), first-generation status (self-reported), binary gender, students who learned a language other than English as their first language (self-reported), and students who worked more than half time (0–19 h per week vs. 20+ hours per week), a factor known to disproportionately affect students from community colleges (Freeman *et al.*, 2020). A point of clarification: although we asked students to report their gender by asking them to choose one of five options: Female, Male, Trans, Gender Nonconforming/Other, or Prefer not to respond, we only used binary gender (Women & Men) in our analysis. We acknowledge the limitations of this approach and regret the discomfort some students in our classes undoubtedly felt. We suspect that students who identify as nonbinary chose one or the other of these binary genders or opted out of the survey altogether. For example, 163 students provided a response to our binary gender question, while 162 students provided an answer to our race/ethnicity question (including "decline to answer").

ANALYSES

How do students experience classes that use warm RC compared with classes that did not use RC?

To understand differences in how students responded to the multiple-choice survey questions, we fit regression models. Four of these questions were answered on a 5-point Likert scale, one was answered on a 4-point ordered scale, and one was answered by selecting from a set of unordered options. Table 1 includes all of the questions, the possible answer options, as well as the abbreviation used in analyses and visualizations.

For the four questions that students responded to on an ordered, Likert-like scale (Table 1), we fit cumulative link mixed models (Theobald *et al.,* 2019) which accounted for the nonindependence inherent in data from students nested in classes and classes taught by different instructors (Theobald 2018). Specifically, our models included a random intercept for student identity (for repeated measures) as well as instructor course (for nested design), as some students were concurrently or subsequently enrolled in multiple classes (repeated measures) and some instructors taught multiple courses and some courses were taught by multiple instructors. We tested for nonindependence by quarter but did not find any. For the question where students selected responses from a nonordered list, we fit multinomial models. Fitting these models in a multi-level modeling framework in R is currently not supported, so we tested the goodness of fit of the models with and without a fixed effect for a course by instructor effect. In all cases, this fixed effect did not explain sufficient variation to justify inclusion in the final model. All models were fit in R version 4.0.5 (R Core Team 2021).

We tested our hypotheses in a model selection framework, fitting complex models first and using singular elimination of parameters until the best fitting, most parsimonious model was selected. To do this, we used Akaike's Information Criterion, with a correction for small sample size (AICc; Anderson and Burnham, 2004). We considered models within 2 AICc units to be equivalent and in these cases we preferred the simplest model.

The most complex model that we started with tested the hypothesis that students experience classes that use warm RC differently than classes that do not use RC and that some of these differences are amplified for students from groups that are currently and historically minoritized in science, technology, engineering, and mathematics (STEM). Specifically, we tested for differential effects between students of different binary genders (Men and Women), students with different racial identities (PEER and non-PEER), students from different college generational status (First Generation and Continuing Generation), students with different initial exposure to English (students who learned English as their first language and students who did not learn English as their first language, a.k.a. English language learners or ELL), and students who work (more than half time and less than half time).

What benefits and interferences do students perceive when getting called on in class?

To answer research questions RQ2 and RQ3, we used qualitative content analysis (Erlingsson and Brysiewicz, 2017; Hsieh and Shannon, 2005; Kleinheksel *et al.,* 2020) to code students' responses to the following two open response questions: "In what ways did being called on in class support your learning?" and "In what ways did being called on in class interfere with your learning?" We used a conventional content analysis approach, in which each of the three coders (three of the authors, S.M.A., J.G.S., and J.M.) derived coding categories from her independent reading of all the student responses, instead of reading with particular a priori constructs in mind (Hsieh and Shannon, 2005). Each coder used an inductive approach to the text data (i.e., student responses to a particular question) to independently create codes to describe ideas in the data (e.g., pays attention). After this, independent coding of all responses to a survey question from each coder were compiled into a common spreadsheet and the three coders then met (in-person or virtually) for consensus coding. During coding for consensus, codes were reworded, reorganized (e.g., combined, split, or modified), and agreed upon. A codebook was created with consensus of common codes and each coder then recoded the text data with the common codes. Finally, all three coders came to a consensus for all the recoded responses.

Student responses could be assigned more than one code depending on their answer to the question (Supplemental Table S2). All responses were binned to their assigned codes and checked against the codebook for consistency in coding and identification of any discrepancies. That is, all of the responses for each code were examined together by the authors, to verify that all of these responses indeed reflected a particular code. After the final coding was complete, the three coders grouped the codes into categories or themes (Erlingsson and Brysiewicz, 2017) and the coders reached consensus on the labels for each theme and the sorting of the codes into themes. For example, the codes pay attention, come prepared, participation, and be ready with answers were grouped together, because the coders determined that they were all indicators of the theme of Engagement (Erlingsson and Brysiewicz, 2017; Kleinheksel *et al.,* 2020). This process required two rounds to reach consensus and the final identification of themes. These themes described behaviors (e.g., engagement), experiences (e.g., learning), or emotions (e.g., frustration). The themes were derived from the process of reading and coding the student responses and were not from previously identified themes in the literature.

Using codes grouped by themes, we asked if there were themes that students in warm RC classes were more likely to report than students in classes that did not use RC (Table 2, Supplemental Table S3). To do this, we fit logistic regression models with a logit link: the outcome was whether or not a benefit theme (e.g., Engagement, Learning, or Metacognition) was mentioned or whether or not an interference theme (e.g., Frustration, Distress) was mentioned. We included a random intercept for student identity as some students were concurrently or subsequently enrolled in multiple classes. The random intercept accounts for the nonindependence inherent in repeated measures data of this nature (Theobald 2018). We tested for nonindependence by instructor and class (as above), but models frequently failed to converge so we simplified the random effect structure to control for the individuals, which tend to have more nonindependence than other grouping variables (Theobald 2018). We fit separate models for each theme (e.g., Frustration) within each category (benefit or interference); thus, initial models only included an indicator for call type. We chose classes that did not use RC as the reference because we were interested in student-reported differences in experience in classes that used warm RC. As separate models were fit for each outcome, the most relevant comparison is between classes that used warm RC and classes that did not use RC (Not RC) within a theme and not across themes. We selected the most parsimonious model by comparing the model with an indicator for call type to a model that only included an intercept (the null model).

TABLE 2. Percent (number in parentheses) of times themes were coded from students' open-ended responses to benefits versus interference questions, disaggregated by call type

Question	Theme	Warm RC	Not RC
Benefits	Engagement	61.0% (164)	34.5% (58)
	Learning	25.7% (69)	38.1% (64)
	Metacognition	19.3% (52)	23.2% (39)
Interference	Distress	32.1% (85)	27.8% (49)
	Frustration	16.2% (43)	6.3% (11)

RESULTS

How do Students Experience Classes that use Warm RC Compared with Classes that use Not RC?

Overall, students felt very positive about their classroom experience in biology classes at Edmonds College (Figure 2). To

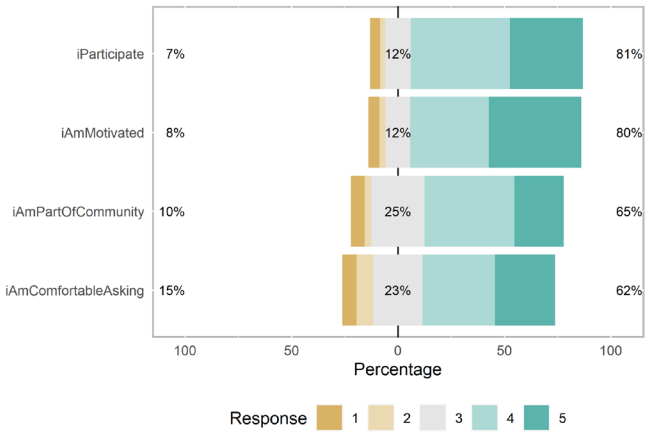

FIGURE 2. Overall students felt very positive about their classroom experience. The Likert scale goes from Strongly disagree (1) to Strongly agree (5). Percentages to the left and right of the bar indicate the number of students strongly disagreeing or disagreeing (left) or the number of students strongly agreeing or agreeing (right).

TABLE 3. Complete Data: Students in classes that use warm RC are more likely to report increased participation by themselves (columns 1 & 2) and their peers (columns 3 & 4).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	I Participate		Others Participate		Motivated		Community		Comfort Asking	
Warm RC	0.660	0.545	1.860	1.710	null	null	null	null	null	null
(ref: non-RC)	(0.255)	(0.167)	(0.266)	(0.175)						
	0.0097	$1.11e^{-03}$	$2.85e^{-12}$	$1.43e^{-22}$						

The estimates are presented as log-odds, standard error of estimate in parentheses, *p*-value below. (Note that backwards model selection was performed using AICc to identify the best fitting model so the *p*-value should be interpreted with caution, if at all.)
All models only include an indicator for warm RC and a random effect (even columns).
Odd columns show effects when including a random intercept for student and unique instructor in a unique class.
We show both estimates with and without the random intercept to demonstrate that they do not vary considerably; for simplicity of interpretation, we plot the effects in probabilities from the models that do not use random effects (even column numbers).
When the null model is the preferred model, "null" replaces estimates.
Note that a null model is a model that only includes an intercept (no predictors) and random effects (if applicable).

understand the extent to which students quantitatively reported their experiences in classes that used warm RC, we modeled six outcomes independently. Table 3 and Table 4 show the model output from complete data ($n = 520$) and Table 5 and Supplemental Table S4 show the model output from the subsetted data that includes demographic breakdown ($n = 156$).

Students in classes that used warm RC were more likely to report participating in class and more likely to report that other students participated in class than students in classes that did not use RC (Figure 3, A and B and columns 1–4 in Table 3). Specifically, the odds of students in classes that used warm RC report participating are 1.9 times that of the odds of students in classes that did not use RC report participating (log odds = 0.66, odds ratio = 1.93, se = 0.26, $p < 0.001$). The odds ratios are even more dramatic for students reporting that others participate: the odds of students in classes that used warm RC report others participating are 6.4 times that of the odds of students in classes that did not use warm RC reporting others participate (log odds = 1.86, odds ratio = 6.42, se = 0.27, $p < 0.001$). There was no difference in how motivated students reported feeling, their sense of community, or their comfort asking questions based on class type (Table 3).

When asked what they would do if they anticipated being called on in class, students in classes that used warm RC were less likely to select *come to class with high anxiety that interferes with [their] learning* compared with students in classes that did not use RC (Table 4, Figure 4). Specifically, the odds of students in classes that that did not use RC reporting they would come to class with high anxiety that interferes with their learning were 2.65 times higher than the odds of a student in a class that used warm RC reporting this (log odds = –0.98, se = 0.33, $p < 0.001$). This was the only statistically significant difference between classes that used different call types. There were, however, differences within (i.e., not between) classes: Students in classes not using warm RC were more likely to select they are likely to *be engaged in class and somewhat anxious about being called on* compared with *participate without worrying about being called on* (odds ratio = 1.61, log odds = 0.48, se = 0.18, $p < 0.001$). Students in classes that did not use RC were less likely to select that they would skip class to avoid speaking in class than to report they would participate in class without worrying about being called on (inverse of the odds ratio = 10.4, so the increased odds of reporting participating without worry, log odds = –2.34, se = 0.47, $p < 0.001$; Table 4).

TABLE 4. Complete Data: Students in warm RC classes are less likely than students in non-RC classes to report coming to class with high anxiety that interferes with learning.

Level	Non-RC[a]	Warm RC[a]
Be engaged in class and somewhat anxious about being called on	0.480 (0.176)	0.199 (0.230)
	$6.57e^{-03}$	0.387
Be nervous in class until after I am called on	0.019 (0.195)	–0.176 (0.264)
	0.922	0.505
Come to class with high anxiety that interferes with my learning	–0.262 (0.210)	–0.976 (0.330)
	0.212	$3.08e^{-03}$
Skip class to avoid speaking in class	–2.342 (0.468)	–1.199 (0.857)
	$5.69e^{-07}$	0.162

[a]Values report odds ratios and are relative to the reference group, "Participate without worry." Significance tests come from Wald's test: significance on Non-RC estimates compare the value to zero thus are testing the null hypothesis that the given estimate is not different than the estimate of the reference, significance on warm RC estimates compare the warm RC estimate to Non-RC estimate thus are testing the null hypothesis that there is no difference in the probability of selecting this level if a student is in a warm RC or non-RC class.
There are no other differences between the two class/call types but note that students are more likely to report being engaged in class and somewhat anxious than Participating without worry in nonRC classes and are much less likely to report being likely to skip class to avoid speaking than Participating without worry in warm RC classes.
The effects are from a multinomial regression model and presented as log-odds, standard error of estimate in parentheses, p-value below. (Note that backwards model selection was performed using AICc to identify the best fitting model so the *p*-value should be interpreted with caution, if at all.)

TABLE 5. Subsetted Data: Students in classes that use warm RC report higher perceived participation from others (columns 3 & 4) than students in classes that do not use RC; this difference is larger for women than for men.

	(1)[a]	(2)[b]	(3)[a]	(4)[b]	(5)[a]	(6)[b]	(7)[a]	(8)[b]	(9)[a]	(10)[b]
	I Participate		Others Participate		Motivated		Community		Comfort Asking	
Warm RC			2.499[c]	2.083[c]						
(ref: non–RC)			(0.555)	(0.364)						
			6.82e^{-06}	1.05e^{-08}						
			2.263[d]	1.939[d]						
			(0.526)	(0.325)						
			1.66e^{-05}	2.30e^{-09}						
Binary Gender Men			1.735	1.486						
(ref: Women)			(0.718)	(0.590)						
			1.6e^{-02}	1.18e^{-02}						
BinaryGender:RC			–1.766	–1.505						
(ref: Women, non–RC)			(0.884)	(0.733)						
			4.6e^{-02}	4.0e^{-02}						
English First					0.878	0.839			1.072	1.008
(ref: ELL)					(0.336)	(0.301)			(0.350)	(0.294)
					8.89e^{-03}	5.35e^{-03}			2.2e^{-03}	6.08e^{-04}
Work 20+ hrs	0.957	0.830	0.802	0.683						
(ref: work 0–19 hrs)	(0.385)	(0.311)	(0.364)	(0.310)						
	0.0129	7.73e^{-03}	2.7e^{-02}	2.75e^{-02}						

[a]Odd columns random factors included a random intercept for unique students and a random intercept for a unique instructor/class combination.
[b]For simplicity of interpretation, Figure 5 shows the effects in probabilities from the models that do not use random effects: the even column numbers.
[c]Warm RC effects correspond with model that includes Binary Gender by RC interaction.
[d]Warm RC effects correspond with model that includes amount of time spent Working.
Students who work more report more participation (columns 1 & 2) and perceive more participation from their peers, regardless of call type they experience (columns 3 & 4).
We show both estimates with and without the random intercept (even and odd columns respectively) to demonstrate that they do not vary considerably.
Estimates are presented as log-odds, standard error in parentheses, *p*-value below. (Note that backwards model selection was performed using AICc to identify the best fitting model so the *p*-value should be interpreted with caution, if at all.)
When a parameter is not retained in the final model, the cell is blank. Each demographic variable was tested in a separate model.

Effects on Students from Minoritized Groups

Trends in the overall dataset are generally similar when considering only the subsetted data (i.e., the subset of data from the last two quarters of student responses that has demographic data; Figure 5), but there are some differential effects for some students depending on their identity. Students who work more than 20 h per week are more likely to report that they participated in class (compared with students who work 0–19 h per week), regardless of enrollment in classes that used warm RC or that did not use RC (Table 5, Figure 5C). Specifically, the odds of students who work more reporting that they participate are 2.6 times higher than the odds of students who work less (odds ratio = 2.6, log odds = 0.96, se = 0.39, p = 0.01). Interestingly, in the subsetted data, class type (RC or Not RC) was never retained in the final model predicting how students answer the question "I participate in discussions in class." This is likely an artifact of the subsetted data being a much smaller sample (e.g., 87 students experiencing warm RC vs. 280 in the nonsubsetted data).

In addition, students who work 20+ h per week are more likely to perceive greater participation by their peers (odds ratio = 2.23, log odds = 0.80, se = 0.36, p<0.001), and students in classes that used warm RC are more likely to report greater participation by their peers than students in classes that did not use RC (odds ratio = 9.6, log odds = 2.26, se = 0.53, p < 0.001; Table 5, Figure 5B). Finally, there is a

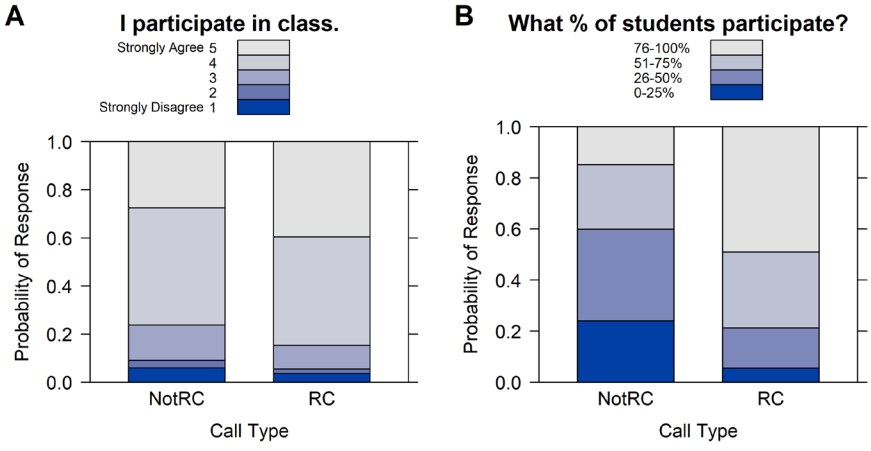

FIGURE 3. Students in classes that use warm RC are more likely to strongly agree that they participate in class (A) than students in classes that do not use RC (Not RC in figure). Students in classes that use warm RC are more likely to report a greater percentage of the students in class participating than students in classes that do not use RC (B). These effects are summarized from the complete dataset and correspond to columns 2 and 4 in Table 3.

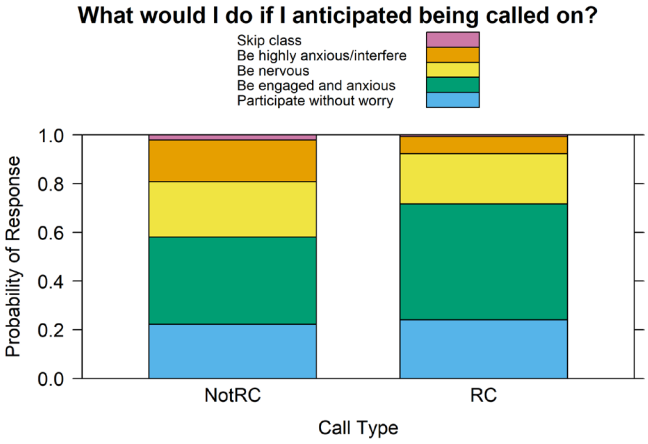

FIGURE 4. Students in classes that use warm RC are less likely to report being highly anxious such that their anxiety would interfere with their learning if they anticipated being called on, compared with students in non-RC classes. These effects are summarized from the complete dataset and correspond to Table 4.

disproportionate perception of who participates for men versus women in the two types of classes. Specifically, women in classes that did not use RC do not perceive as much participation from their peers compared with women in classes that used warm RC, but importantly, there is no difference in what men perceive in the two class types. In other words, the difference between men's and women's perception of peer participation is smaller in classes that used warm RC than in classes that did not use RC (Table 5, Figure 5A) because women perceive more participation in classes that used warm RC. For example, the percentage of women who perceived 76–100% of students participating in classes that used warm RC was more than twice that of the percentage of women who perceived this level of participation in classes that did not use RC (Table 5; Figure 5A).

Students who report learning English as their first language report greater motivation and greater comfort asking questions in class than ELL students who report not learning English as their first language, regardless of their call experience in class (Table 5, Figure 5, D & E). The odds of a student who reported learning English first also reporting higher motivation was 2.4 times greater than the odds of ELL students also reporting

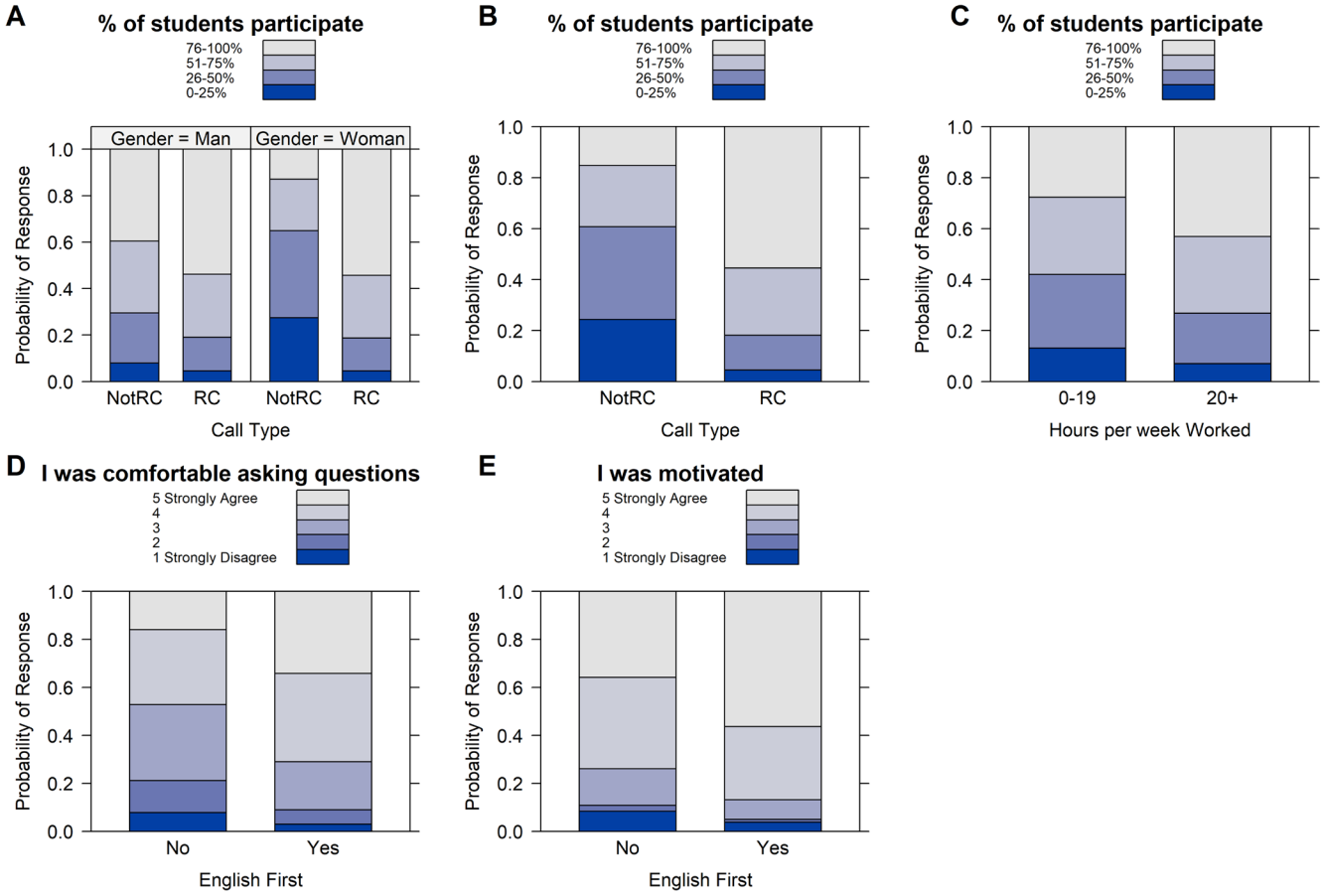

FIGURE 5. Students in classes that use warm RC are more likely to report a higher percentage of students participating than students in classes that do not use RC and this difference is greater for women than men (A). In addition, controlling for hours per week worked, students in classes that use warm RC report more participation from their peers (B) and students who themselves work more perceive more participation from their peers (C). In addition, students who report learning English as their first language are more comfortable asking questions in class (D) and are more likely to report stronger agreement with being motivated in class (E), regardless of call type. For quantitative effects, see Table 5.

higher motivation (odds ratio = 2.4, log odds = 0.88, se = 0.34, $p < 0.001$). The odds of a student who reported learning English first also reporting greater comfort asking questions in class was 2.9 times greater than the odds of ELL students also reporting greater comfort (odds ratio = 2.9, log odds = 1.07, se = 0.35, $p < 0.001$). Finally, nothing we tested (call type or demographics) was predictive of student agreement of feeling like they were part of a community (Table 5, Figure 2). We found no other differential association between classes that use different call types and student identity.

In the subsetted dataset, there was no difference in how students reported they would feel if they anticipated getting called on if they were in classes that used or did not use warm RC. Rather, students who reported learning a language other than English as their first language were less likely to report they would *skip class* than report they would *participate without worry* (Table S4 and Supplemental Figure S1; reciprocal odds ratio = 6.0, log odds = –1.792, se = 0.62, $p < 0.001$). Said another way, the odds of a student who reported learning English as their first language and that they would skip class were 6 times higher than the odds of an ELL student also reporting they would skip class. It is worth noting that no students who report learning English first also selected *skip class to avoid speaking in class*, making it impossible to estimate the effect of learning English first on reporting skipping class (Supplemental Table S4 and Figure S1).

What Benefits do Students Perceive when Getting Called on in Class?

To explore how students think getting called on benefits their learning, we asked students how being called on in class supported their learning. Through thematic analysis, we found nine codes associated with support for student learning (a tenth code included did not support Table 6A, Supplemental Figure S2). These codes were further categorized into three themes (Table 6A, Supplemental Figure S2).

For example, our analysis showed that some students perceived hearing from their peers as beneficial to their learning:

> Being called on **helped me to follow along in the lecture** as well as **considering ideas & perspectives put forth by other students** that I hadn't thought of (from a student in a class that did not use RC). Codes: pay attention and understanding

> It let me know what **parts of the readings were important to focus on in the class**, plus it helped to learn what my classmates had learned (from a student in a class that used warm RC). Code: understanding

> It encourages you to come up with some sort of answer and think about the problems, rather than being provided the answers and copying them down. You never know when you'll have to answer. It also encourages you to answer whatever you think, even if it's mistaken, and sometimes perspectives are given that are relevant but wouldn't necessarily be in a standard lecture (from a student in a class that used warm RC). Code: practice articulating thoughts

Finally, although these codes were not abundant, we did find that students expressed getting called on benefits their learning because it allows some of our students to practice articulating thoughts and develop confidence.

> Having to verbalize the concepts we were learning and getting feedback on our ability to do so was very helpful (from a student in a class that used warm RC). Code: practice articulating thoughts

> Being called in class boosts my learning and also helps me build confidence in what I know (from a student in a class that used warm RC). Code: develop confidence

As the above responses show, student responses showed a mix of benefits if they anticipated being called on that fell under three themes: Engagement (e.g., pay attention), Metacognitive (e.g., develop confidence), and Learning (e.g., understanding, practice articulating thoughts). Thus, we grouped codes based on these three themes (Supplemental Figure S2) to explore if there were any benefits more prevalent in warm RC classes compared with non-RC classes.

When considering theme-level responses, students in classes that used warm RC were way more likely to report being engaged as a benefit to being called on in class, compared with students in classes that did not use RC (Figure 6A, Table 7). Specifically, the odds of students in classes that used warm RC reporting Engagement were 3.39 times higher than for students in classes that did not use RC (odds ratio = 3.39, log odds = 1.22, se = 0.25, $p = 1.07e^{-6}$). Students in classes that used warm RC were less likely to report Learning as a benefit of being called on, compared with students in classes that did not use RC (odds ratio = 0.51, log odds = –0.67, se = 0.25, $p = 0.008$). The difference between a student recognizing an aspect of Metacognition as a benefit was much smaller, such that there was no distinguishable difference in students' responses coded for these two themes in the two types of classes (Figure 6A, Table 7). Note that the remaining "significant" coefficients on the interactions in Table 7 are comparing the differences between the blue points in Figure 6A, not the differences between the green and blue points in each benefit type.

A more granular look at the codes within the themes revealed that come prepared, pay attention, understanding, and identify understanding were the most abundant codes with come prepared, participation, and pay attention stated more often in classes that used warm RC compared with classes that did not use RC (Supplemental Table S3; Figure S2). Specifically, 26.4% of codes were come prepared in classes that used warm RC compared with only 12.5% in classes that did not use RC. Similarly, pay attention (28.6% vs. 19.0%) was more often reported in classes that used warm RC (Supplemental Figure S2 and Table S3). In agreement with the quantitative data, participation as a benefit to getting called on was higher when students were answering the survey in classes that used warm RC (11.9% in classes that use vs. 6.0% in classes that do not use RC; Supplemental Table S3; Figure S2).

Students who selected that they would *come to class with high anxiety that interfered with their learning* if they anticipated getting called on ($n = 60$ students) still reported benefits to getting called on in class, including come prepared, develop confidence, identify understanding, pay attention, understanding, participation, practice articulating thoughts and recall (Supplemental

TABLE 6. Codes and themes for student responses to the question: *In what ways did being called on in (A) class support and (B) class interfere with your learning*?

A			
Theme	**Code**	**Description**	**Example**
Engagement	come prepared	provided incentive for students to learn material (e.g., readings, assignments, practice quizzes) before class	*"It made sure I did the reading and knew what was being talked about"*
Engagement	pay attention	increased focus, attention or engagement in class	*"Made me more engaged in class."*
Engagement	be ready with answers	prepared answers to anticipated questions	*"Encouraged me to have an answer ready to everything"*
Engagement	participation	participated actively in discussions and activities in class	*"… ensuring that participating in class and make me "actively learn" especially whenever I got answers wrong."*
Learning	Recall	facilitated student learning at Blooms level one or "knowledge"	*"Required me to recall information even when I didn't feel that the information was in my head."*
Learning	understanding	facilitated student learning at Blooms level two or "understanding"	*"helped me learn new information if I didn't know the answer"*
Learning	practice articulating thoughts	explained their thought process with feedback	*"Having to verbalize the concepts we were learning and getting feedback on our ability to do so was very helpful."*
Metacognition	identify understanding	identified the accuracy and depth of their understanding	*"I checked my knowle[d]ge by answering questions in class. It let me think about material deeply."*
Metacognition	develop confidence	increased confidence, self-assurance and/or belief in one's knowledge, skills or abilities	*"Participating will help us on developing our self confidence, be more active and study in advance material for the next class, make us feel appreciate it and be part on our own learning in front of our classmates, be more confident and be able to speak up our ideas and knowledge."*
	did not support		*"I feel it's a lot of unnecessary pressure and doesn't correlate much with whether [yo]u do well in class o[r] not."*
B			
Theme	**Code**	**Description**	**Example**
Frustration	time away from learning	perceived as wasting limited class time	*"I could find it frustrating at times if I know an answer and want to share it, or feel the need to correct what's being said. I also feel things can be missed if they aren't explained the rest of the way. And it seems so random that some people never actually get called."*
Frustration	dualism	expected that instructor has the one right answer	*"It is hard to learn when people are just guessing at things that are already known. It is easier to learn if we are just told what is known instead."*
Frustration	dominator	missed the opportunity to share their understanding and to correct others	*"I could find it frustrating at times if I know an answer and want to share it, or feel the need to correct what's being said."*
Distress	social anxiety	embarrassed or felt awkward speaking in the presence of others	*"as someone who has difficulty speaking in front of crowds the pressure makes it hard to think when all ears are waiting for your answer. Even if I knew it I'll only be thinking about how all focus is on me."*
Distress	performance anxiety	concerned with not knowing the right answer	*"Being afraid of being wrong."*
Distress	learning anxiety	worried that being called on made learning more difficult	*"It made me stop my train of thought so my understanding wasn't as clear."*
Distress	anticipation distraction	expressed trepidation that interfered with focus in class and was a distraction	*"Most time I was thinking, omg is it my turn next so it kind of mess up my concentration a bit"*
Distress	generalized anxiety	felt nervous, anxious, fearful or uncomfortable	distress for some students: *"It created an environment in which I didn"t feel comfortable."*
Eustress	generalized anxiety	felt nervous, anxious or uncomfortable but generally helpful	eustress for some students: *"Sometimes I was nervous but overall I it helped my learning."*
Eustress	productive anxiety	felt anxiety or nervousness, but recognized it as helpful for recall and understanding	*"i get nervous when am being called but this helps because i am able to remember the answer."*
	Does not interfere		*"I was comfortable with being called. No learning interference."*

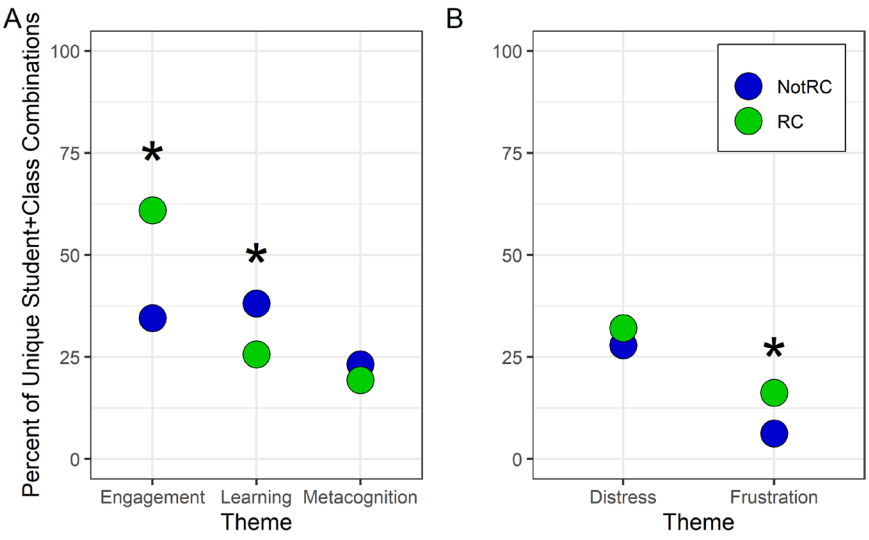

FIGURE 6. Students in classes that use warm RC were more likely to report Engagement compared with students in classes that did not use RC, and students in classes that did not use RC were more likely to report Learning than students in classes that did use warm RC (A). Students in warm RC classes were more likely to report Frustration than students in classes that did not use RC (B). There were no differences in student responses across call types for the other themes: metacognition (A) or distress (B). Asterisks indicate significance from logistic regression models (Table 7).

Figure S4A). In addition, those who selected they would *skip class to avoid speaking* ($n = 7$ students) reported discussing with classmates and asking clarifying questions as benefits. For those who selected that they would *be engaged but anxious* or *be nervous* if they knew they would be called on, benefits associated with learning—including pay attention, come prepared, identify understanding and understanding—were all more abundant responses than those that did not support code. A few students ($n = 5$) who selected *come to class with anxiety* if they anticipated being called on also addressed their anxiety as being productive to learning. We realize that this open-ended question asked all students to report a benefit to their learning, so these responses are not the exclusive experiences of students (see below for the interferences students report). Also, we note that we cannot be certain if students are reporting these benefits as benefits to their own learning or perceived benefits to other students' learning.

What Interferences do Students Perceive when Getting Called on in Class?

To explore how students report getting called on interferes with their learning, we asked students "In what ways did being called on in class interfere with your learning?" We found ten codes associated with interfering with student learning. An 11th code included did not interfere (Table 6B, Supplemental Figure S3). These codes were further categorized into two themes (Table 6B; note that the third theme in Table 6B "Eustress" is discussed below). Themes were grouped based on 1) anxiety and actions associated with distress versus 2) codes that exhibited an incompatibility with how students thought they learned best and/or what a learning environment should look like. The latter codes were grouped into a theme we termed Frustration. We used this theme because the quotes indicated a feeling of being upset or annoyed, especially with respect to interfering with their ability to learn or obtain the perceived correct answer. The student quote below and three quotes at the top of Table 6B reflect aspects of frustration.

> **Time was wasted when people were called on** who didn't know **the answer**, and it **occurred somewhat frequently that several people** would need to be **called on** (Code: time away learning) before the correct answer would be given (Code: dualism, i.e., the belief that there is one right answer).

TABLE 7. Log odds of students reporting themes (within benefits or interferences) in classes that use warm RC versus classes that do not use RC.

			Estimate	Std Error	*z* value	*p*-value
Benefits	Engagement	**intercept**	–0.7193	0.1926	–3.734	1.88E–04
		RC	1.2211	0.2503	4.878	1.07E–06
	Learning	**intercept**	–0.5986	0.2009	–2.98	0.00288
		RC	–0.6665	0.2508	–2.658	0.00787
	Metacognition	**intercept**	–9.3937	0.7904	–11.88	<2e–16
		RC	NA	NA	NA	NA
Interferences	Frustration	**intercept**	–19.74	3.196	–6.176	6.57E–10
		RC	9.148	2.546	3.593	3.27E–04
	Distress	**intercept**	–1.0111	0.1659	–6.094	1.10E–09
		RC	NA	NA	NA	NA
	General Anxiety	**intercept**	–8.9523	0.7915	–11.31	<2e–16
		RC	NA	NA	NA	NA

Estimates come from logistic regression models that include a random intercept for student identity.
Not RC was the reference category, so the effect of warm RC is reported in the table.
All estimates shown were retained in the final model.
Results are shown in Figure 6.

When we examined these codes and themes, the most abundant interference code was "did not interfere" (Supplemental Table S3). These responses were analyzed as zeros for other codes because we were specifically interested in interferences. Furthermore, we found that, generally, students did not report being frustrated (16.2% in classes that used warm RC and 6.3% in classes that don't use RC), but that students who experienced warm RC were more likely to express frustration than students who did not experience RC (Table 7; odds ratio = 9.148, se = 2.55, $p < 0.001$). We didn't find any other difference between students in classes that used warm RC and those in classes that did not use RC in the number of times that students report interference codes or themes (Figure 6B, Table 7, Supplemental Table S3).

General anxiety and other forms of anxiety were abundant interference codes (Table S3). As we coded student responses, we found cases where students reported anxiety, but it was not always associated with interfering with their learning, and student responses showed that anxiety could promote various levels of engagement (Table 6B and Table 8). Finally, some student responses suggest instructor implementation of calling on students may be important in shifting some anxiety toward more positive feelings during open discussion (Table 8).

DISCUSSION

How do Students Experience Classes that use warm RC compared with Classes that Do Not Use RC?

Students reported benefits as well as drawbacks to getting called on in class. Our data support previous findings that students recognized the benefits of RC in the classroom, such as increased engagement and paying attention (*Broeckelman-Post et al., 2016)*. In classes that used warm RC, we found that students self-reported participating in class more (Table 3) and that they heard more of their peer's voices (Table 3) than in classes that did not use RC (e.g., that used volunteer call). Similarly, Broeckelman-Post and colleagues found that students reported they listened more carefully to student responses to questions when RC was being used in the classroom (2016).

The quantitative results support that students in classes that use warm RC perceive greater student participation than students in classes that do not use RC (Table 3, Figure 3). Our findings indicate that students are aware that a larger number of voices contribute to the discussion in classes that use warm RC and that a greater number of voices can benefit their learning. Many studies support the connection between student participation at four-year institutions and a deeper understanding of concepts, higher grades, and positive impacts on student learning and participation (Gasiewski *et al.,* 2012; Eddy *et al.,* 2015; Knight *et al.,* 2016; Theobald *et al*., 2020). However, this connection is under-explored in the community college context. We have no reason to believe that the link between participation, understanding, and outcomes would be qualitatively different for community college students, but because this population is significant and generally under-explored (Schinske *et al*., 2017), it is worth further characterizing these linkages.

While students in classes that used warm RC reported different perceptions of group and individual participation, there was no notable difference between the likelihood of a student reporting being part of a community, being motivated to do well, or being comfortable asking the instructor questions between classes employing different call types (Table 3).

TABLE 8. Student responses show feelings of anxiety lead to different levels of engagement/learning

Eustress: Anxiety promoted benefits to student engagement/learning.	
Code: come prepared, productive anxiety	"It kind of forces people to fear getting called on so it may help people by forcing them to be fully prepared for class. I think the biggest fear people have is having the fear of getting an answer wrong when they're called on. So if we are in a class where people are called on constantly, it will force people to study more efficiently before class"
Code: pay attention	"I was not very comfortable with being called at first, but later I realized it helped me to stay a little more nervously focused in class since you never know when you would be called next"
Neustress: Anxiety is present but it does not impact learning.	
Code: general anxiety	"I would sometimes get anxious but it wasn't a big impact on my learning."
Code: did not interfere; general anxiety	I wouldn't say it interfered with anything. I just have bad anxiety and don't like being put on the spot.
Distress: Anxiety leads to negative impacts on learning/student engagement.	
Code: general anxiety	"It gave me anxiety and then I didn't want to participate much."
Code: general anxiety; anticipation distraction	"Makes me nervous hence distracts my attention from class"
Instructor implementation mitigated some student anxiety and provided a safe space for open discussion.	
Code: productive anxiety	"Being called on in class would give me a little anxiety especially if I didn't know the answer, but I quickly learned that that was okay in this class."
Code: productive anxiety	"Sometimes I got really anxious and afraid to say "i don't know" but I have overcome that issue the more I do it"
Code: develop confidence; identify understanding	"When I got answers correct, it gave me confidence. When I got them wrong, I had an opportunity to learn why I thought wrong. It was the way my instructor asked, and how the instructor corrected me that was helpful - without condemnation or making me feel "stupid.""
Code: not applicable to the open-ended question	"having the ability to PASS if needed, and not be made to feel that you were a failure for doing so."

Certainly, feeling part of the community, being motivated, and being comfortable asking questions may be affected by other variables that are associated with individual instructors' personalities and practices (Allen *et al.*, 2006, Schussler *et al.*, 2021). Furthermore, students at our college already have high agreement in each of these areas (Figure 2), a trend that is consistent in the literature among community college students in introductory biology courses (Freeman *et al.,* 2020).

We found that students had different perceptions of classes in the subset of students in which we were able to disaggregate responses by student identity. Both men and women were more likely to report a higher percentage of students participating in classes that used warm RC versus classes that did not use RC (Table 5, Figure 5), but there was a disproportionate perception for women: Women perceived disproportionally more participation than men between the two class types. This result may help address findings reported in Grunspan *et al.* (2016): they reported that "males are more likely than females to be named by peers as being knowledgeable about course content…and that this bias in nominations is specifically due to males over-nominating their male peers relative to their performance." Dallimore *et al.* (2019) found that use of random cold call increased gender equity in class discussions, resulting in increased participation of all students and that of women, in particular. We speculate that the use of warm RC may help alleviate gender bias in classroom discussions by encouraging women to speak more in class (Nadile *et al*. 2021). When only a few students speak in class, students have a skewed perception of who best understands the material in a class. With a larger diversity of voices heard in the classroom, students may be less likely to fall into the gender or racial bias associated with a few voices dominating the discussion. Indeed, Grunspan *et al.* (2016) found that in the one class in their study that used RC, there was a trend for women to consider other women as very knowledgeable, effectively decreasing the magnitude of bias toward men as the most knowledgeable students. Further research is needed for specifically investigating the impacts of the use of warm RC on students' perceptions of who will do well in the class.

We also found that students who report learning English as their first language are more comfortable asking questions in class and are more likely to report stronger agreement with being motivated in class regardless of call type they experienced (Table 5; Figure 5, D and E). Although the data appear to indicate that the few students who selected they would *skip class to avoid speaking* identified as ELL, it is important to note that no students who had English as their first language selected *skip class to avoid speaking in class* (Supplemental Table S4 and Figure S1). There is a paucity of data that directly addresses how RC directly impacts ELL in the classroom. Our data suggest that warm RC may interfere with learning because ELL may be more uncomfortable asking questions than other students and at least a few may *skip class to avoid speaking in class.* Metzger and Via (2022) propose additional warm call approaches that may be a strategy to reduce anxiety for ELL. Their advance student preparation warm call approach provides students with more time to prepare their responses by either alerting students that they will be the next to share during class or emailing questions and prompts 24–48 h in advance of class (Metzger and Via 2022). Also emphasizing that responses are optional and not assessed (i.e., graded) may reduce the anxiety of being called on for some ELL students.

While these differential trends are interesting and promising, it is important to note that we began collecting our demographic data in the last two quarters of our study and therefore it is only a subset of the data. Furthermore, demographics related to students with disabilities were not gathered nor considered in the analysis. Students with disabilities face additional challenges associated with warm RC which may be addressed with accommodations in the classroom (Gin *et al.*, 2020). As a result, the inferences one can make from this data are limited. Future research focusing on the skew in gender perceptions of who is participating in the classroom and the impacts of warm RC on students that are ELL will help to elucidate how warm RC impacts these populations of students.

What Benefits do Students Perceive Getting Called on in Class?

When students were asked how getting called on benefited their learning, they reported a number of things that we coded into the themes Engagement, Learning, and Metacognition (Figure 6, Table 6A). Pay attention, come prepared, and participation were more often reported by students in classrooms using warm RC, while recall and understanding were more often reported from students in classes that did not use RC (Supplemental Figure S2; Table S3). The increase in the codes categorized under Engagement further demonstrates that students are aware that each individual is expected to be and is engaged in classes that use warm RC. Previous studies on the use of notecards for student participation and discussion reported similar increases. For example, Brigati and colleagues (2019) found that many students perceive verbal questions and other forms of active learning to enhance student engagement, even if instructors do not identify this as a benefit of being called on. In addition, Broeckelman-Post (2016) found that students reported a great number of positive responses when the instructor used notecards to call on students (positive $N = 250$, negative $N = 142$), including *engagement out of class* and *engagement in class* (Broeckelman-Post 2016).

If students perceive that being called on directly impacts their ability to learn and therefore perform better on graded work, this may be perceived as eustress as opposed to distress. Rudland and colleagues (2020) include increased focus as a result of a learning expectation, or "stressor", that occurs with eustress. Thus, while students may experience more stress in classes that implement warm RC, it may be that RC helps students prioritize accountability for learning expectations more easily dismissed in classes that do not use RC. Overall, students' perceptions of increased participation, and student engagement associated with come prepared and pay attention align with why instructors at our community college and larger research universities (Waugh and Andrews, 2020) implement RC.

While we have focused on warm RC as one way to include all student voices in classroom discussion, other practices have been implemented that aim to provide an expectation of student participation in discussion without an increase in additional distress (Huseby, 2022; Metzger and Via 2022). Two of these practices, the rotating front row (RFR) (Huseby, 2022) and prior preparation for warm call (Metzger and Via, 2022) provide students with advanced notice on participating in class.

This is different from our implementation of warm RC because our students were not alerted to when they would be called on. In RFR, similar student responses to our study were found including feeling confidence to speak up, benefits to hearing other people contribute, and feeling more inclination to participate (Table 6A; Huseby, 2022). In addition, Huseby (2022) also found fear of negative evaluation (i.e., performance anxiety; Table 6B) as well as no impact on learning due to study habits and behaviors (i.e., speaking in class without RFR) the student already had. Thus, warm RC adds to a growing list of pedagogical practices that has the potential to provide more diverse and equitable participation during class.

What Interferences do Students Perceive when Getting Called on in Class?

While active learning practices, including RC, have been shown to have multiple benefits, many studies have also highlighted the negative impacts to active learning in both research university and community college settings (Cooper *et al.,* 2018; Downing *et al.,* 2020). In particular, a fear of negative evaluation and judgment by peers was associated with cold call/ RC and led some students to report avoidance by skipping class (Cooper *et al.,* 2018). We directly tested this hypothesis in our context by asking our students how they would feel if they knew they would be called on in class. Students chose one of five unordered categorical answers, which included *skip class to avoid speaking in class* as an option. Very few of our students selected this option (n = 7 of 520 total, i.e., 1.3%), and only 2 of those students were in classes that used warm RC (n = 2 of 286 total in classes that used warm RC, i.e., 0.69% vs. n = 5 of 234 total in classes that did not use RC, i.e., 2.1%). Furthermore, students in classes that used warm RC were less likely to select *come to class with high anxiety that interferes with my learning* than students in classes that did not use RC (Table 4; Figure 4). These patterns give us hope that our implementation of warm RC in our community college biology classes does not have the same detrimental effect reported in Cooper *et al.* 2018.

These differences in context could also be influenced by differences in preparation, implementation, or timing (Waugh and Andrews, 2020). For example, after the initial stress of warm RC in the classroom, some evidence from our qualitative data suggests that students' anxiety associated with being called on in class decreases as they become more comfortable with the warm RC structure (Table 8). Other studies have demonstrated an increase in comfort while participating in class discussions in courses with high cold call (Dallimore *et al.*, 2013). It is important to note that in the Dallimore *et al.* (2013) study, instructors used cold call, as compared with our courses where warm RC was used. This is an important distinction because cold call is perceived as more stressful because students are not given time to discuss the question before being called on.

We also examined the benefit and interference codes based on how students responded to the categorical questions in the survey. While students reported various feelings of anxiety associated with the idea of being called on, this anxiety was associated with student perceived benefits to being called on in class. Participation and understanding were codes found across all responses associated with the categorical question "If I anticipate being called on in class I am likely to" (Supplemental Figure S4). We also found that while many students indicated types of anxiety as interfering with their learning, additional codes associated with Frustration were also prevalent, especially in those students who did not report as much anxiety if they anticipated being called on (Supplemental Figure S4).

When examining our interference codes, the "did not interfere" code was the most common (Supplemental Table S3). This supports our findings that, overall, students have positive experiences in our biology classrooms (Figure 2). General anxiety (code, Table 6B), on the other hand—represented as a variety of student responses including "not comfortable", "nervous" and "fear"—was also reported across call types. This code, however, was removed from the analysis because it was not always used in a negative context: students do not always have a negative association with anxiety and in some cases, it can even be seen as beneficial to their learning (Table 8). Given that anxiety is often a measure used when looking at practices associated with active learning, our varied student responses about anxiety suggest that it is important to examine anxiety in the context of gains and costs to learning (England *et al.* 2019).

In our study, all instructors that used warm RC used the same general method. Implementation of warm RC by these instructors included all of the critical components identified in Waugh and Andrews (2020) and earlier suggestions to "warm up cold call" (Dallimore *et al.*, 2006; Metzger and Via, 2022), including: 1) introducing warm RC on the first day of class and consistently using it as a way to call on students throughout the course, 2) allowing students to talk to each other before getting called on, 3) selecting a speaker for a group and/or posing the question so that the student is reporting what a group discussed, 4) being respectful and positive for all answers that students share, and 5) allowing the opportunity for students to "pass" if needed. Instructors in our study also used a common set of lecture slides that addressed the types of call that could be used to promote class discussion, how calling on students can help instructors assess what is being learned throughout the class, and why a particular type of call would be used on the first day of class (Supplemental Appendix C). While students were not asked about the critical components of warm RC directly in our survey, one student in a class that used warm RC mentioned that instructor implementation of warm RC did "*[provide] a safe space for open discussion.*" These sentiments were echoed by other students who even addressed implementation easing their anxiety (Table 8) and can be seen in some of the individual student quotes in Downing *et al.* (2020) when students saw instructors normalizing incorrect answers and validating student thinking. Taken together, our data suggest that the critical components Waugh and Andrews (2020) identified based on instructor interviews are things our students also perceived as beneficial.

The responses to how getting called on benefits and interferes with student learning support the idea that while warm RC may increase stress, the anxiety felt by a student may not always be detrimental to learning or student engagement. Some students reported that the stress associated with getting called on could be productive (Table 6A; Table 8) and codes associated with behavioral engagement were significantly higher from students who took the survey in courses implementing warm RC (Figure 6A and Supplemental Figure S2). In addition, students reported that getting called on prompted them to pay attention more in class and may be similar to the "Increase Focus" that Rudland *et al.* (2020) associated with

eustress. A large majority of students in our classes aspire to go on to health professions where stress will be a regular part of the job. Our results suggest that some anxiety may be mitigated by instructor implementation and allows students to meet the learning expectations and benefits associated with RC, specifically engagement. This is consistent with the results of Dallimore *et al.* (2019) that the voluntary participation of women could be increased by RC. Given that implementation and context for using warm RC impacts student learning, future work that addresses and assesses Instructor Talk as well as assessments of eustress and distress may provide a clearer and more thorough picture for the benefits and drawbacks to warm RC.

The Vision and Change report (AAAS, 2011) includes the ability to communicate as a core competency for undergraduate biology education, and oral communication is recognized as a key skill in the STEM workplace (Hart Research Associates 2018; Clemmons *et al.,* 2020; Koerber *et al.,* 2021). Thus, as suggested by others (Waugh and Andrews, 2020; Metzger and Via, 2022) warm RC can provide the opportunity for all students to practice these skills early in their academic career.

Limitations and Future Work

It is important to note that although we tried to be conservative in our interpretation of these data, there are clearly limitations of this study. First, the survey questions were developed for this study alone, as there were no existing survey instruments for being called on in class. In addition to this, we did not collect extensive validity data on the questions we asked. That said, we developed these questions because we were initially interested in whether or not these community college biology students would skip class if they anticipated being called on in class as reported previously in the literature (i.e., Cooper *et al.*, 2018). We relied heavily on one quantitative survey question ("If I anticipate being called on in class, I am likely to…") as well as emergent student answers in open-ended qualitatively evaluated questions to test this hypothesis. Relying on emergent answers to open-ended qualitative questions is problematic because it is never clear if lack of mention is synonymous with "it wasn't an issue." In this way it is hard to code for true absences in qualitative data. Furthermore, it can be problematic to rely on a single quantitative question (as we have done) for a variety of reasons, including but not limited to the fact that 1) this question is only a single question that addresses a complex suite of possible emotional and behavioral responses, 2) students were forced to choose among the answers we provided (and we did not provide an option for students to "decline to respond" or select multiple responses), and 3) we did not validate this question. Additional validity data, particularly from think aloud interviews with students to gather face validity, would be useful to ensure that students understood both the questions and answer responses in ways that are consistent with our interpretation. In addition, think-aloud interviews would also lend credence to our decision to ask all of our questions as a single response, assuming that students would select the single answer that best described their experience. And finally, additional questions could have better triangulated students' responses to the anticipation of being called on in class. Nonetheless, our results that students did not report (or select) being overly worried to the extent that they would skip class was reassuring and noteworthy.

Second, as is typical in community college classrooms, our sample size was small, particularly when disaggregating the data by student demographics. While we are confident in our estimates of the whole population, our disaggregated subsetted data should be interpreted with caution; in some cases, we report on results from very few students. Future work should include continuing to collect demographic information from surveys to explore any disproportionate benefits and drawbacks of RC, especially warm RC, to students from minoritized groups in STEM.

Third, context matters. Perhaps our student population is unique in ways that correlate with willingness to endure warm RC without huge interferences. As this is the first study, we know of to explore the impacts of consistent and relatively uniform implementation of warm RC on community college students, it is worth continuing to test these hypotheses in community college, small class-size contexts as well as exploring other contexts (i.e., larger class sizes and upper division vs. lower division courses).

Fourth, it is important to recognize the limitations of this as an observational study, and not a controlled experiment. Specifically, instructors chose whether or not to use warm RC - so neither students nor instructors were assigned to a treatment condition. In our study, no instructor taught both a class that used warm RC as well as a class that did not. Although several instructors contributed to this study (using both call types), it is difficult to fully isolate warm RC from other instructor characteristics (and confounding variables) in the current design. Some possible confounding variables that future studies should consider include things like course content, instructor identity and experience, course structure, active learning/evidence-based practice versus lecture, etc.

Finally, while our models did control for individual students (because a single student appeared in our dataset in different classes), we were not able to test the hypothesis that "dosage" matters. In other words, our data were not collected to understand if students' previous experience with RC influences how they perceive warm RC in a particular class. For example, a student in the third course in a series (e.g., BIOL& 213) compared with a student in the first course in a series (e.g., BIOL& 211) may experience warm RC in different ways because of prior exposure to a similar implementation of warm RC. Our analyses do not test this hypothesis, nor do we control for this factor. To better approach this question, we have begun to implement the survey as a presurvey during the beginning of the course. These survey responses can then be paired with the survey done at the end of the course for a more direct measure of benefits and interferences warm RC has on student learning. Given that students often progress through multiple biology classes after enrolling at Edmonds College, it may be possible to track these students and explore the idea of "dosage" in more detail as our work continues.

Based on student responses, additional exploration into the types of anxiety students report (i.e., eustress versus distress) would contribute to a better understanding of the students' experiences when being called on in class. By dissecting sources of stress into benefits and interferences, we can better determine how to modify the implementation of warm RC such that we capitalize on the benefits and alleviate interferences students experience during class discussions.

CONCLUSIONS

In summary, we find that there are many potential benefits to warm RC in our community college biology classes. Many students report being more engaged, hearing from more students, and perceive other benefits to their learning. While not all students report these benefits – some students are extremely anxious, and for some warm RC interferes with their learning – these drawbacks were experienced by the small minority of students in our context. We champion continued exploration of warm RC in STEM classes and the need to disaggregate data and better dissect student reports of stress so that we understand the impact of warm RC on all our students.

ACKNOWLEDGMENTS

This work was supported, in part, by the *Community College Biology Instructor Network to Support Inquiry Into Teaching and Education Scholarship,* CC Bio INSITES network and meeting services from the Howard Hughes Medical Institute (HHMI). We also thank the biology instructors who took the time to implement this survey in their course.

REFERENCES

Allen, M., Witt, P. L., & Wheeless, L. R. (2006). The role of teacher immediacy as a motivational factor in student learning: Using meta-analysis to test a causal model. *Communication education*, *55*(1), 21–31.

American Association for the Advancement of Science (AAAS) (2011). *Vision and change in undergraduate biology education: A call to action*, Washington, DC: American Association for the Advancement of Science.

Anderson, D., & Burnham, K. (2004). *Model selection and multi-model inference* (2nd ed.) (pp. 10). New York, NY: Springer-Verlag.

Brigati, J., England, B. J., & Schussler, E. (2019). It's not just for points. *Journal of college science teaching*, *48*(3), 45–55.

Broeckelman-Post, M., Johnson, A., & Reid Schwebach, J. (2016). Calling on students using notecards: Engagement and countering communication anxiety in large lecture. *Journal of College Science Teaching*, *45*(5), 27–33.

Clemmons, A. W., Timbrook, J., Herron, J. C., & Crowe, A. J. (2020). BioSkills guide: Development and national validation of a tool for interpreting the vision and change core competencies. *CBE—Life Sciences Education*, *19*(4), ar53.

Cooper, K. M., Downing, V. R., & Brownell, S. E. (2018). The influence of active learning practices on student anxiety in large-enrollment college science classrooms. *International Journal of STEM Education*, *5*(1), 1–18. https://doi.org/10.1187/cbe.20-08-0200

Cooper, K. M., Schinske, J. N., & Tanner, K. D. (2021). Reconsidering the share of a think–pair–share: Emerging limitations, alternatives, and opportunities for research. *CBE—Life Sciences Education*, *20*(1), fe1. https://doi.org/10.1187/cbe.20-08-0200

Dallimore, E. J., Hertenstein, J. H., & Platt, M. B. (2006). Nonvoluntary class participation in graduate discussion courses: Effects of grading and cold calling. *Journal of Management Education*, *30*(2), 354–377.

Dallimore, E. J., Hertenstein, J. H., & Platt, M. B. (2013). Impact of cold-calling on student voluntary participation. *Journal of Management Education*, *37*(3), 305–341.

Dallimore, E. J., Hertenstein, J. H., & Platt, M. B. (2019). Leveling the playing field: How cold-calling affects class discussion gender equity. *Journal of Education and Learning*, *8*(2), 14–24.

Downing, V. R., Cooper, K. M., Cala, J. M., Gin, L. E., & Brownell, S. E. (2020). Fear of negative evaluation and student anxiety in community college active-learning science courses. *CBE—Life Sciences Education*, *19*(2), ar20. https://doi.org/10.1187/cbe.19-09-0186

EdComm, American Society of Cell Biology Education Committee, (2017). *Taking the terror out of random call [Blog post]*. Retrieved September 15, 2021 from https://www.ascb.org/careers/taking-terror-random-call/

Eddy, S. L., Brownell, S. E., & Wenderoth, M. P. (2014). Gender gaps in achievement and participation in multiple introductory biology classrooms. *CBE—Life Sciences Education*, *13*(3), 478–492.

Eddy, S. L., Converse, M., & Wenderoth, M. P. (2015). PORTAAL: A classroom observation tool assessing evidence-based teaching practices for active learning in large science, technology, engineering, and mathematics classes. *CBE—Life Sciences Education*, *14*(2), ar23.

Eddy, S. L., & Hogan, K. A. (2014). Getting under the hood: How and for whom does increasing course structure work? *CBE—Life Sciences Education*, *13*(3), 453–468.

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine*, *7*(3), 93–99.

England, B. J., Brigati, J. R., & Schussler, E. E. (2017). Student anxiety in introductory biology classrooms: Perceptions about active learning and persistence in the major. *PloS one*, *12*(8), e0182506.

England, B. J., Brigati, J. R., Schussler, E. E., & Chen, M. M. (2019). Student anxiety and perception of difficulty impact performance and persistence in introductory biology courses. *CBE—Life Sciences Education*, *18*(2), ar21.

Freeman, S., Pape-Lindstrom, P., Casper, A., & Eddy, S. (2020). Community College Students Rise to the Challenge. *Journal of College Science Teaching*, 49(5)

Gasiewski, J. A., Eagan, M. K., Garcia, G. A., Hurtado, S., & Chang, M. J. (2012). From gatekeeping to engagement: A multicontextual, mixed method study of student academic engagement in introductory STEM courses. *Research in Higher Education*, *53*(2), 229–261.

Gin, L. E., Guerrero, F. A., Cooper, K. M., & Brownell, S. E. (2020). Is active learning accessible? Exploring the process of providing accommodations to students with disabilities. *CBE—Life Sciences Education*, *19*(4), es12.

Gross, D., Pietri, E. S., Anderson, G., Moyano-Camihort, K., & Graham, M. J. (2015). Increased preclass preparation underlies student outcome improvement in the flipped classroom. *CBE—Life Sciences Education*, *14*(4), ar36.

Grunspan, D. Z., Eddy, S. L., Brownell, S. E., Wiggins, B. L., Crowe, A. J., & Goodreau, S. M. (2016). Males under-estimate academic performance of their female peers in undergraduate biology classrooms. *PloS one*, *11*(2), e0148405.

Harrison, C. D., Nguyen, T. A., Seidel, S. B., Escobedo, A. M., Hartman, C., Lam, K., ... & Tanner, K. D. (2019). Investigating instructor talk in novel contexts: Widespread use, unexpected categories, and an emergent sampling strategy. *CBE—Life Sciences Education*, *18*(3), ar47.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research*, *15*(9), 1277–1288.

Hart Research Associates. (2018). *Fulfilling the American dream: Liberal education and the future of work*. Washington, DC: Association of American Colleges and Universities.

Hood, S., Barrickman, N., Djerdjian, N., Farr, M., Gerrits, R. J., Lawford, H., ... & Hull, K. (2020). Some believe, not all achieve: The role of active learning practices in anxiety and academic self-efficacy in first-generation college students. *Journal of microbiology & biology education*, *21*(1), 10.

Hood, S., Barrickman, N., Djerdjian, N., Farr, M., Magner, S., Roychowdhury, H., ... & Hull, K. (2021). "I Like and Prefer to Work Alone": Social Anxiety, Academic Self-Efficacy, and Students' Perceptions of Active Learning. *CBE—Life Sciences Education*, *20*(1), ar12.

Huseby, M. (2022). The Rotating Front Row increases student-reported participation during discussion. *Journal of Microbiology & Biology Education*, *23*(3), e00316–21.

Kleinheksel, A. J., Rockich-Winston, N., Tawfik, H., & Wyatt, T. R. (2020). Demystifying content analysis. *American Journal of Pharmaceutical Education*, *84*(1), 127–137.

Knight, J. K., Wise, S. B., & Sieke, S. (2016). Group Random Call Can Positively Affect Student In-Class Clicker Discussions. *CBE—Life Sciences Education*, *15*(4), ar56.

Koerber, A., Provencher, J., & Starkey, J. (2021). Leadership Communication in the STEM Workplace: A Qualitative Study. *Technical Communication Quarterly*, *30*(2), 123–142.

Martin, S. N., Milne, C., & Scantlebury, K. (2006). Eye-rollers, risk-takers, and turn sharks: Target students in a professional science education program. *Journal of Research in Science Teaching*, *43*(8), 819–851.

Metzger, K. J., & Via, Z. (2022). Warming Up the Cold Call: Encouraging Classroom Inclusion by Considering Warm-& Cold-Calling Techniques. *The American Biology Teacher*, *84*(6), 342–346.

Nadile, E. M., Williams, K. D., Wiesenthal, N. J., Stahlhut, K. N., Sinda, K. A., Sellas, C. F., ... & Hutt, A. E. (2021). Gender differences in student comfort voluntarily asking and answering questions in large-enrollment college science courses. *Journal of microbiology & biology education*, *22*(2), e00100–21.

Novak, G. M., Patterson, E. T., Gavrin, A. D., & Christian, W. (1999). *Just-in-time-teaching: Blending active learning with web technology*, Upper Saddle River, NJ: Prentice Hall.

Pella-Donnelly, M. (2009). It's as simple as shuffling cards. *Science Scope*, *32*(9), 56.

R Core Team (2021). *R: A language and environment for statistical computing. R Foundation for Statistical Computing*, Vienna, Austria. Retrieved from https://www.R-project.org/

Rudland, J. R., Golding, C., & Wilkinson, T. J. (2020). The stress paradox: How stress can be good for learning. *Medical Education*, *54*(1), 40–45.

Schinske, J. N., Balke, V. L., Bangera, M. G., Bonney, K. M., Brownell, S. E., Carter, R. S., ... & Corwin, L. A. (2017). Broadening participation in biology education research: Engaging community college students and faculty. *CBE-Life Sciences Education*, *16*(2), mr1.

Schussler, E. E., Weatherton, M., Chen Musgrove, M. M., Brigati, J. R., & England, B. J. (2021). Student Perceptions of Instructor Supportiveness: What Characteristics Make a Difference? *CBE—Life Sciences Education*, *20*(2), ar29.

Seidel, S. B., Reggi, A. L., Schinske, J. N., Burrus, L. W., & Tanner, K. D. (2015). Beyond the biology: A systematic investigation of noncontent instructor talk in an introductory biology course. *CBE—Life Sciences Education*, *14*(4), ar43.

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). *The challenges of defining and measuring student engagement in science*.

Tanner, K. D. (2011). Moving theory into practice: A reflection on teaching a large, introductory biology course for majors. *CBE—Life Sciences Education*, *10*(2), 113–122.

Tanner, K. D. (2013). Structure matters: Twenty-one teaching strategies to promote student engagement and cultivate classroom equity. *CBE—Life Sciences Education*, *12*(3), 322–331. https://doi.org/10.1187/cbe.13-06-0115

Theobald, E. J. (2018). Students are rarely independent: When, why, and how to use random effects in discipline-based education research. *CBE—Life Sciences Education*, *17*(3), rm2.

Theobald, E. J., Aikens, M., Eddy, S., & Jordt, H. (2019). Beyond linear regression: A reference for analyzing common data types in discipline based education research. *Physical Review Physics Education Research*, *15*(2), 1–21.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., ... & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476–6483.

Waugh, A. H., & Andrews, T. (2020). Diving into the Details: Constructing a Framework of Random Call Components. *CBE—Life Sciences Education*, *19*(2), ar14.