The Impact of a Bookend Think-Pair-Share Intervention on Anxiety and Student Collaboration in a Community College Human Physiology Course

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Abstract
Pre-clinical community college students represent a unique population with varied academic backgrounds and levels of preparedness. Addressing the needs of this population is important for issues of access, equity, and diversity in higher education. As part of a larger National Science Foundation (NSF) funded Community College Anatomy and Physiology Education Research (CAPER), this study aimed to investigate the impact of an active learning technique on student anxiety, student collaboration, and final course grades. We introduced a bookend think-pair-share (TPS) active learning technique into a traditional community college human physiology lecture. The study found an increased likelihood of collaboration, a slight increase in final grades, a slight decrease in social anxiety, and a significant decrease in anxiety regarding five of eight specific teaching practices following the bookend TPS intervention. https://doi.org/10.21692/haps.2019.030

Key words: anxiety, think-pair-share, peer instruction, active learning, community college

Introduction
Community college students aiming for careers in the health sciences arrive with varied academic backgrounds and wide-ranging levels of preparedness. These students often struggle with success in Human Physiology courses, a common prerequisite for many allied health programs. Community colleges, which are generally two-year open-enrollment public institutions, have a distinctive mission compared to many four-year universities, including serving those students with less access to traditional higher education. But, with broader access often comes a diverse student population: community college students are more likely to be first-generation status (36% v. 25% at 4-year), lower socioeconomic status, and have less experience with prior academic achievement than most students at 4-year institutions (Fong et al. 2017). These students are also very likely to be employed part-time or full-time and to be of nontraditional age (Juszkiewicz 2015). Therefore, when assessing issues of access, equity, and diversity in higher education, it is crucial to consider the unique factors impacting community college student success.

Students in college biology courses also often struggle with understanding and verbalizing the causal reasoning for physiological phenomena (Michael 1998). Both the language of physiology and difficulty interpreting physiological graphs, equations, and flowcharts can make the material in Human Physiology classes challenging to master (Michael 2007). Although lecturing is a traditional delivery method for a Human Physiology course, collaborative active learning approaches such as Peer Instruction (i.e. think-pair-share or TPS) have been shown to improve student performance in science and health-care related classes (Sumangala and DiCarlo 2018; Freeman et al. 2014; Prahl 2017).

Poor performance in science courses correlates with increased student anxiety and a low sense of academic self-efficacy and often has implications beyond the courses in question (Bandura 1977). Students with higher levels of anxiety perceive tests as threatening and tend to think they have less control over outcomes. High levels of academic anxiety correlate with a decreased likelihood of success on assessments and a negative experience with the educational process. Negative experiences are important considerations for the community college student, because negative experiences encourage disengagement from formal academic learning in a population with fewer academic successes to fall back on (Cassady 2004).

Research has shown that one effective strategy to decrease student anxiety and improve academic self-efficacy is to provide mastery experiences that have the same or similar tasks as a future summative assessment task (Bandura 1977). Low-stakes formative assessment opportunities, in which students can discuss and correct their knowledge can provide opportunities for mastery, decrease anxiety, and result in

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better performance in summative assessments. Fostering a collaborative, rather than competitive, classroom culture, with peer interaction, may also help reduce the negative impacts of student anxiety.

Mazur (1997) describes a structured series of steps called Peer Instruction (i.e. think-pair-share or TPS) designed to emphasize student interaction during lectures and focus students' attention on the underlying concepts. The method begins with a short conceptual multiple-choice question called a "ConcepTest" that focuses on a single topic. The type and phrasing of the question matters, though; open-ended ConcepTest questions that require verbalization of processes to arrive at a conclusion foster student interaction and discussion more effectively than questions that require a simple recall of information (Allen and Tanner 2005). After presenting the ConcepTest question, the instructor allows students time to answer the question alone, then provides time to consult with peers and answer the question again, and finally presents the correct answer and provides an opportunity for discussion with the class (Mazur 1997).

The TPS technique can easily be modified to include personal response systems (PRS) to ensure that every student is participating in the activity and to allow the instructor to give immediate feedback based on responses received. Another modification to the TPS technique is to use the ConcepTest question to "bookend" a traditional lecture by posing the question, allowing for students to answer individually, then lecturing over the concept (but not the specific question), before posing the same question again, this time allowing time for TPS and class discussion. This modification encourages students to focus attention on the concept initially with the presentation of the question, allows them time to process and critically evaluate their initial response, and prepares them for the discussion that they will have when they engage in the collaboration step (Smith et al. 2005). Integrating TPS opportunities within a traditional lecture format provides students the opportunity to verbalize their thoughts about physiological concepts using appropriate terminology, to correct misconceptions in a low-stakes environment, and promotes communication and comparison of ideas among classmates, and can encourage a collaborative, rather than competitive, classroom culture, especially if the instructor helps to foster inquiry and reinforces the process as well as correct responses. Paired or small group discussion can also decrease the anxiety often associated with students speaking out in class, providing a less daunting opportunity to verbalize ideas with one or a few peers first (Tanner 2013).

Mazur (1997) states that TPS, "forces the students to think through the arguments being developed and provides them (as well as the teacher) with a way to assess their understanding of the concept". TPS has also been shown to improve performance on quizzes (Sumangala and DiCarlo 2018). In addition, if, as reported, students find the causal reasoning associated with Human Physiology difficult, then modeling and providing opportunities to practice this kind of reasoning during class (using carefully worded ConcepTest questions) with real-time instructor feedback could lead to higher summative assessment scores and decreased stress (Michael 2007).

Although TPS has been implemented and evaluated in multiple studies, we did not find evidence in the literature that the bookend TPS technique had been tested in the community college population.

As part of a larger study on pedagogical practices in anatomy and physiology courses at the community college level, this research introduced a bookend TPS technique administered with electronic personal response systems into a traditional lecture-based human physiology course and attempted to answer three questions:

1. Does a bookend TPS activity administered during formative assessment improve final grades?
2. Does the use of a TPS activity decrease student anxiety?
3. Does a TPS activity increase the likelihood of student collaboration?

Methods

Student Population

This research was implemented in two 30-student Human Physiology (BIOL2420) lecture sections taught at Salt Lake Community College (SLCC) by the same instructor. Each class met twice per week for 80 minutes. Students enrolled in Human Physiology at SLCC are primarily second-year students majoring in pre-health science or an undeclared major. The majority of these students intend to apply to nursing programs or other allied health programs such as radiology, occupational therapy assistant, and physical therapy assistant. SLCC students are required to complete Introductory Biology and Elementary Chemistry with a C or better as a prerequisite for Human Physiology, and most students have also completed Human Anatomy, although it is not a prerequisite for the course. Students must also enroll in Human Physiology laboratory (BIOL2425), as a corequisite. Human Physiology is often the last course a student will take before applying to an allied health program or transferring to a four-year college to complete a bachelor's degree. At SLCC, 42% of our student population self-report as first generation, whereas 42% report as not first generation and 14% do not report their status. Moreover, 75% of the student population works more

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than 30 hours per week (Figure 1). Thus increasing in-class comprehension in this population with less formal academic experience and considerable time constraints is crucial to student success.

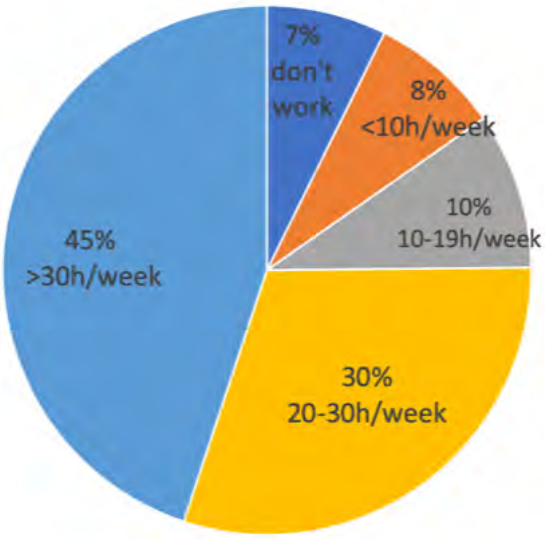

Figure 1. *Working students at SLCC*

Bookend Think-Pair-Share

The Institutional Review Board (IRB) of Salt Lake Community College found this research project to be exempt form IRB review (IRB# 00009566, FWA00021259). Informed consent was obtained from all participants. TPS questions were administered during two 80-minute lecture sections per week during Spring semester 2019. During most lecture periods, a conceptual multiple-choice question was presented twice (with a short lecture between the questions). Using Top Hat, an electronic PRS, students answered the question alone, then listened to the material, then collaborated and answered again, comparing answers to other student answers, with the instructor providing anonymous histograms of student responses and real-time feedback. Mazur (1997) describes the seven steps that constitute the traditional Peer Instruction method as follows.

1. Students are presented a conceptual multiple-choice question (ConcepTest question). Questions followed published guidelines for designing effective multiple-choice questions, with a correct answer and viable distractors that elicit common misconceptions about the concept (Haladyna et al. 2002). An example ConcepTest question is provided in Figure 2.

All of these factors impact stroke volume. Which of these do you predict will DECREASE stroke volume?

A **increased venous return to the atria**

B **increased strength of ventricular contraction**

C **increased pressure in the arteries near the heart**

D **increased blood volume in the ventricles**

Figure 2. *Sample ConcepTest question.*

2. Students were then given one minute to think before answering the question.

3. Students respond using PRS. Student responses and correct answers were not shared with the class at this point. As a modification to Mazur's original Peer Instruction method, at this point a short lecture was presented about the physiological concept assessed in the ConcepTest question. The lecture did not cover the specific question, or the answer the ConcepTest question, but guided students through understanding the concept and modeled logic that could be used in answering the question and the vocabulary used to explain the concept.

4. The same question was presented again after the short lecture. During the collaboration portion students were asked to pair with another student and discuss what each initially answered. Students attempted to convince their partner if their answers differ and to verbalize their arguments whether they agreed or disagreed. Students were instructed to use physiological terminology presented in the lectures when appropriate and to be prepared to discuss their answers with the class. This TPS portion was allotted three to five minutes.

5. Students were given one minute to answer the same question again.

6. The correct answer and an anonymized student response histogram were shared with the class. Students are awarded credit for participation (not for accuracy) for answering the question alone and in pairs. This was an important component of TPS that encourages collaboration and correcting misconceptions.

7. Instructor asked students to share their logic about correct answers and distractors and guided a class discussion about the reasoning used to arrive at the correct answer.

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Because research indicates that providing mastery experiences with the same or similar questions used on summative assessments can reduce student anxiety, similar questions to those used during think-pair-share were used on summative assessments as multiple choice, essay, or short answer questions (Bandura 1977).

Grade Analysis

In order to assure both students and the college IRB that assignment of final course grades was not influenced by participation in the study, grade analysis was performed only after final student grades were reported to the college. Final grades after the intervention were compared to final grades in a previous semester of the same course from the same instructor, which was used as a control. The previous course used for comparison was randomly selected, had approximately the same enrollment (30-35 students), also met for 80-minutes twice per week, used PRS (but not TPS), used the same lecture text, had similar lecture exams, and had the same laboratory activities.

Anxiety and Collaboration

Students were asked to complete a self-report measure rating their agreement with statements related to anxiety on a Likert scale at the beginning and the end of the semester. To test whether social anxiety changed with the treatment, we performed a dependent t-test on student reports of social anxiety using a modified Mini-SPIN general and social anxiety inventory before (N=67) and after the treatment (N=51) (Connor et al. 2001, Pintrich and DeGroot 1990). Test anxiety was measured using items from the Revised Test Anxiety Scale (RTA) (McIlroy et al. 2000).

Student anxiety regarding specific in-class teaching practices was measured using items from an existing sub-scale of a validated instrument designed to measure anxiety levels toward research, modified to measure anxiety levels toward biology instruction (England et al. 2017). We tested for differences in anxiety pre- and post-treatment about eight in-class teaching practices: listening to a PowerPoint lecture, volunteering answers posed by the instructor, answering cold-call questions, individual low-stakes (<5% of grade) quizzing, group low-stakes quizzing, TPS, PRS quizzing in pairs, and PRS quizzing alone. Significant differences in task-related anxiety were identified using MANOVA using SPSS statistical software (Field 2013).

Student responses to the question "Do you have any comments or suggestions about the use of Think-Pair-Share, especially in challenging courses?" were subjected to thematic analysis. The comments were examined for common themes, and trigger words for each theme were identified. Two researchers, other than the course instructor, independently calculated the number of times each theme appeared in the comments. The independent researchers compared their results and came to a consensus.

At the end of the semester, students were also asked whether the intervention impacted the likelihood that they would form a study group or collaborate with other students. Open-ended comments from students regarding the intervention were collected and will be presented in the results section.

Results

Grades

Students performed better on each bookend TPS question after a short lecture and collaborating with their peers. Although students were given credit for participation regardless of the accuracy of answers, we calculated the percent correct on each bookend ConcepTest question, before and after collaboration. On average, students scored 62% correct on ConcepTest questions before collaboration and 86% correct after (Figure 3).

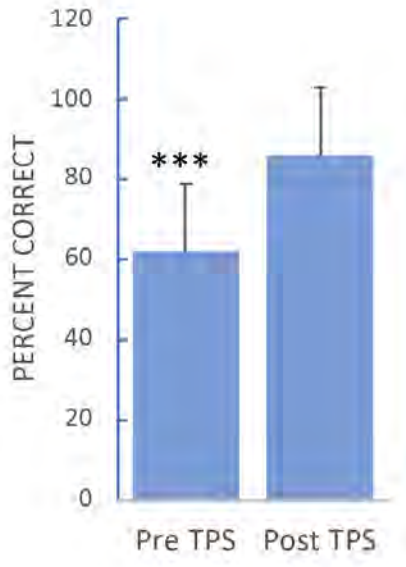

Figure 3. *Percent correct responses to ConcepTest questions, pre- and post-TPS collaboration (mean +/- SD; ***, P<0.001).*

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We assessed whether this modified TPS technique administered during formative assessments improved final course grades. In order to test this, we ran an independent t-test comparing the final grades of a randomly-selected previous spring semester (in which the technique wasn't used) to the final grades of this semester. We found a modest, but not significant, difference, in which students using the bookend TPS instruction technique performed slightly better (mean = 83.0827 *SD* = 13.38369) compared to those students from a previous semester who did not use the technique (mean= 78.5590, *SD* =14.45638), $t(111) - 1.72$, $p = .089$.

Anxiety

While Mini-SPIN measures of social anxiety were lower in the post test (N= 51 M = 2.97 SD = 1.20) compared to pretest (N=67 mean=3.24 *SD* = 1.06), this difference did not reach significance, $t(48) = 1.628$, $p=.11$.

A MANOVA of anxiety reports regarding eight specific in-class activities showed a significant difference in anxiety levels from pre to post, $F(3,46) = 8.434$, $p < .001$ (Figure 5). Follow-up univariate analysis reveals that there was no significant anxiety difference in three of the activities: listening to a lecture, volunteering answers posed by the instructor, and cold-calling from the instructor. However, both PRS activities (alone and with a partner) showed that mean anxiety about the activity decreased significantly in the post test compared to pretest (for conditions alone and with another student).

Mean anxiety regarding low-stakes quizzing (alone and with a group) also decreased significantly in the post test compared to pretest, for conditions with a group and alone, respectively.

Mean anxiety about the specific intervention, TPS, decreased significantly in the post-test compared to the pretest.

	Beginning of term (n=67)	**End of term (n=51)**	*p*
	Mean Anxiety +/- SD	Mean Anxiety +/- SD	
Total social anxiety	3.24 ± 1.06	2.97 ± 1.20	0.11
Task-specific anxiety			
Group low-stakes quiz	2.24 ± 1.27	1.8 ± 0.978	< 0.05
Individual low-stakes quiz	2.36 ± 1.12	1.73 ± 0.850	< 0.001
TPS	2.1± 1.12	1.67 ± 0.971	< 0.01
PRS pairs	2.42 ± 1.17	1.92 ±1.077	< 0.01
PRS individual	2.3 ± 1.20	1.57 ± .677	< 0.001

Table 1. *Mean perceived anxiety, pre- and post-intervention, (0 = no anxiety, 5= extreme anxiety)*

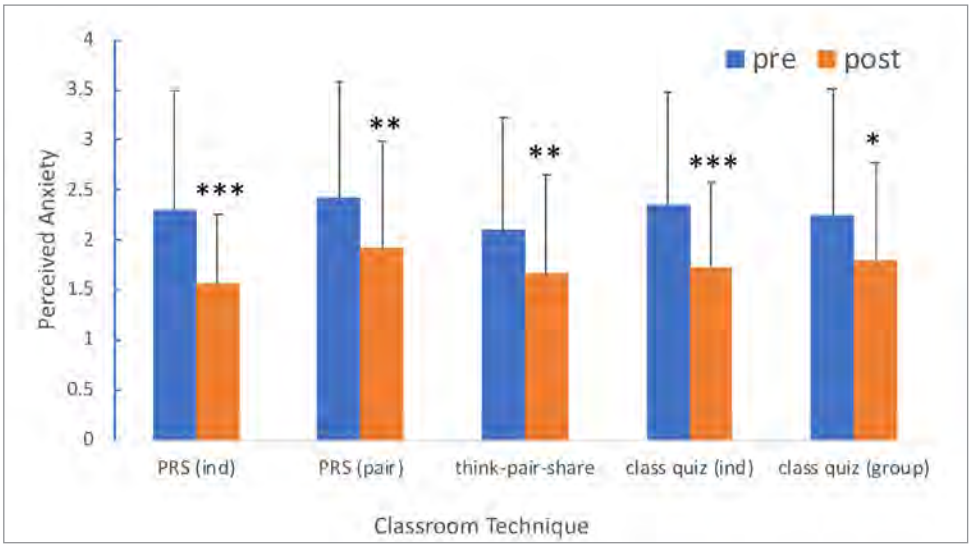

Figure 4. *Perceived task-related anxiety pre- and post-intervention (mean +/- SD; *, <0.05; **, P<0.01; ***, P<0.001, MANOVA). Students reported task-related perceived anxiety on a scale of 1 (low anxiety) to 5 (extreme anxiety).*

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Thematic analysis of open-ended comments

Thirty-four students provided response to the open-ended question "Do you have any comments or suggestions about the use of Think-Pair-Share, especially in challenging courses?" As shown in Table 2, six overlapping themes were identified. Thirty-two of the thirty-four comments conveyed a positive perception of the think-pair-share technique, and (15) indicated that they found the group aspect especially helpful. Four students commented that the discomfort or anxiety associated with group work helped their learning; an equal number indicated that the anxiety impaired their ability to learn. Students also indicated that the technique helped them prepare for exams (4) and/or fostered deep learning and critical thinking (6).

Theme	Explanation	Trigger Words	Sample Comment	n (out of 34)
Positive Perception	Student experiences the implementation of Think-Pair-Share in a positive way	• Helpful • Useful • Enjoy • Beneficial • Effective • Great • Liked • Loved	"I think that think-pair-share should be used in every class. it was very useful to have to think it through in your own words and to get a second explanation from another student."	32
Enabling Discomfort/ Anxiety	The discomfort/ anxiety the student experiences when participating in Think-Pair-Share activities enables the student's learning or contributes to growth	• Comfort zone • Step out • Talk • Peers • Get out • Nervous • But • Helped	"I was really nervous about it at the beginning of the semester but I found it very helpful and was glad we used it"	4
Impairing Discomfort/ Anxiety	The discomfort/ anxiety the student experiences as a result of the implementation of Think-Pair-Share impairs the student's ability to learn	• Anxiety • Anxious • Insecure • Intimidating • Time factors • Loud	"Some of them were a little tricky and I have bad anxiety when time is a factor on things."	4
Test Preparation	Student found Think-Pair-Share useful for test preparation	• Exams • Test • Questions • Material • Study • Prepare • Expect	"I think that the think-pair-share activity made me think about the material before I learned the material. this alone really helped my study. I tried to use these types of methods in later times that I studied."	4
Group Learning	Student found the group aspect of Think-Pair-Share useful	• Group • Peers • Partner • Collaborate • Discuss(ion)	"Being able to collaborate and talk about the questions with people in the class I wouldn't have otherwise talked to was extremely helpful."	15
Deep Learning	Student prioritizes deep understanding of class concepts	• Critical thinking • Engage(ing/ed) • Understand • Concepts • Material • Reasoning	"I think more teachers should use think-pair-share. it helps with critical thinking, gets the class involved and engaged, and I felt like it helped me understand the material better."	6

Table 2. *Student responses to the question "Do you have any comments or suggestions about the use of Think-Pair-Share, especially in challenging courses?"*

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Student collaboration

We polled students (N=67) at the end of the term to see if they were more or less likely to collaborate or study with peers following a semester of TPS intervention. Thirty-five percent reported that they were more likely, 42% reported that the likelihood was about the same, and 1% reported that they were less likely. Some positive and negative comments regarding student collaboration are presented below. Both the survey and the student comments seem to indicate that most students are more likely to collaborate with their peers following the intervention.

Positive comments	Negative comments
Being able to collaborate and talk about the questions with people in the class i wouldn't have otherwise talked to was extremely helpful. Whether I was getting help from them or teaching them, I was always learning.	Yes it forces you to work with others, but it doesnt facilitate a way to make the group work any less intimidating.
It was very useful to have to think it through in your own words and to get a second explanation from another student. it made understanding difficult concepts easier because students would explain it in "layman's" terms.	For the share portion, I think it would be good to encourage collaboration with different students each time. It's helpful to mix it up and be exposed to different ways of thinking and approaches. I normally don't like working out the answer with other people but it actually helped a lot to hear them explain and help me to learn it more.
It allowed me to learn from my peers or teach them things that I felt I knew well. It also broke the ice for the people around me forcing us to interact. this made it easier to colab with the people that I did the tps with.	It help a little but can also be hard when you don't really know anyone or the answer to the questions being asked you can feel more insecure about things you don't know.
I really enjoyed answering the question alone first, learning material and then coming back to it and collaborating with classmates	
I liked the think pair share because I learned to think about the question on my own, learn the material from the professor, then go over the question again with my peers and having it explained to me differently and having the opportunity to explain it to them to make sure I really understand the material.	

Table 3. *Selected student comments regarding collaboration.*

Discussion

Although active learning techniques, student collaboration, and student anxiety have been studied extensively, a gap remains in the literature regarding the impact of specific active learning techniques on the community college student experience. The unique challenges of this student population - academic unpreparedness for college-level work, time constraints due to financial stresses, and disproportionately first-generation college student status - necessitate that college instructors reflect carefully about both presentation and assessment. As part of a larger National Science Foundation (NSF)-funded grant encouraging community college instructors to incorporate evidence-based instructional practices in their courses, this study specifically assessed the impact of one practice on the community college student, with specific concerns of these students in mind.

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Course Grades
Students performed better on the conceptual questions after a short lecture and discussion with their peers. Our findings are consistent with earlier demonstrations of the value of social learning, including the value of discussion with peers. Smith et al. (2009) found that peer discussion increases understanding on conceptual questions, even when none of the students in the group initially knows the answer.

There was no statistical difference in final course grades when compared to a previous semester. Further study and a larger sample size may reveal whether the intervention may have an impact on course grades. Regardless, course grades were not negatively impacted, and other factors were significantly positively impacted by the intervention.

Task-specific Anxiety and Social Anxiety
The statistically significant decreases in task-specific anxiety related to PRS quizzing, in-class quizzing and TPS activities were also encouraging, and might indicate that students were more comfortable with both critical thinking - because the ConcepTest questions required application and verbalization of knowledge - and collaboration - because engaging in the TPS activities was a low-stakes interaction with class members. Some reports indicate that close to half of first-generation college students drop out within their first year, and, although most students in this study were second-year students, increasing critical thinking and collaboration in this population could have lasting positive impacts on their academic prospects in any stage of their studies (Xu and Jaggars 2011).

Although it was encouraging that self-reported social anxiety decreased in the post-intervention survey when compared to the pre-intervention survey, this difference also did not reach significance. A larger sample size might allow us to determine whether the recorded lower social anxiety could be attributed to the intervention.

Student collaboration
One encouraging and unanticipated side effect of the bookend TPS intervention was that many students reported that they were more likely to collaborate and study with peers after the intervention. The instructor's role in facilitating a TPS activity is to be clear that students need not get the answer correct or agree in order to benefit, and also to emphasize that practicing the problem-solving aspect of physiology is an essential part of learning about physiology (Tanner 2013). The TPS technique reinforces collaboration by awarding credit for participation in the discussion instead of credit for correct answers, which seemed to be an important consideration for anxious students. By charging students to compare ideas and identify points of agreement and disagreement and then encouraging open discussion, students seemed to get into the practice of verbalizing their ideas. In a challenging course that requires interpreting data and graphs and verbalizing causal reasoning, collaboration with other students should prove beneficial, especially for the less academically experienced student.

Conclusion

Community college students represent a unique population that is often less academically prepared, more pressed for time due to financial obligations and work schedules, and more easily discouraged from academics than the traditional college student population (Fong et al. 2017, Juszkiewicz 2015). Community colleges serve these students by providing broader access to higher education than most 4-year institutions, and consequently community colleges tend to have a more diverse student body. Retaining these students in the STEM disciplines must be a priority, and active learning techniques have been identified as one means of fostering inclusivity and potentially reducing the achievement gap faced by underrepresented groups in STEM (Snyder et al. 2016).

This study investigated a single active learning technique within a single course. Since our study found a decrease in task-specific anxiety about several in-class teaching practices after the intervention, and students also reported greater likelihood of collaboration, this type of intervention may be beneficial for increasing student success and retention in the diverse community college population. Student comments indicated that most students had a positive perception of the intervention, and found the group learning aspect of TPS helpful, an important consideration for the community college student, because negative experiences encourage disengagement from academics, especially in community college students (Cassady 2004). Small group discussion with peers can provide a less intimidating venue to verbalize ideas, practice critical thinking, and collaborate. These results highlight the need for additional research regarding active learning techniques within the community college population.

One notable limitation of this study was the small sample size: only 67 students in two classes over the course of a single semester precludes generalizing the conclusions to larger groups. More power through a larger sample might allow us to detect whether differences in course grades and social anxiety would reach statistical significance. Further study using a control group within the same class or the same semester would allow more confidence that the intervention is responsible for the differences observed. Considering that this study was performed with second-year community college students who already had some experience and success with college-level science courses, future work exploring the technique with first-year community college students, a group that studies indicate is very likely to discontinue their studies when faced with barriers, would be interesting (Xu and Jaggars 2011).

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It would also be interesting to determine whether the patterns indicated by this small study would be reflected with multiple instructors in a larger sample within community college students and/or would vary with university students within the first two years of their STEM studies.

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Acknowledgments

Melaney Farr would like to thank Mike Farr and her supervisors Mary Jane Keleher and Craig Caldwell, for institutional support for this research. This study was funded by a grant from the National Science Foundation: Community College Anatomy and Physiology Education Research (CAPER) Award Abstract #1829157.
We would all like to thank the Human Anatomy and Physiology Society for funding and support, and the entire CAPER team for collaboration and collegiality.

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