

REFORMING BIOLOGICAL/BIOMEDICAL SCIENCE TEACHING AND EDUCATION: A REFLECTION ON WELL-DEVELOPED PRACTICES AND APPROACHES IN LARGE CLASS

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ABSTRACT

Making students efficiently understand and master the knowledge of biology/biomedicine by prompting active learning and critical thinking and making biology/biomedicine courses form an integrated system, are critical for more successful and effective student education. However, the current biological/biomedical education system tends to produce graduates best suited for academic careers in highly specialized areas. Intensively packed curricula that have expeditions instructions are preferred at numerous institutions worldwide. These curriculum instructions prioritize comprehensive subject matter rather than offering more opportunities for training students in significant professional and personal skills, including critical thinking, active learning, and problem-solving skills. In this article, we discuss current defects in biological/biomedical science education and the need to reform biology/biomedicine teaching and education. We are particularly reflecting on approaches/strategies that we develop to improve biology/biomedicine teaching and learning, particularly in large classes that are challenging. This article has implications for students, instructors, and curriculum designers in higher education, and help to face challenges of biology/biomedicine learning.

KEYWORDS:

biomedicine, biology, teaching reform, active learning, student engagement

1. INTRODUCTION

Biomedicine is an interdisciplinary subject and branch of medical science where biological and physiological principles and research data are applied to clinical medical practice. By applying the biological principles and technologies, biological/biomedical sciences can solve the problems in bioscience, playing an important role in the development of modern medical science [1,2]. Therefore, it is critical to identify and develop approaches that can improve the effective understanding and mastering of the biological/biomedical science knowledge by students within a short period of time. These approaches are also required for making courses of the biomedical science form an integrated system that can enhance student performance, learning and future career [1,2].

In the last two decades, the biomedical/biological science education worldwide prioritizes the production of graduate students who are more appropriate for postdoctoral trainings and specialization in their areas of interests [3,4,5]. This has led to enhancing the commitments of these graduate students to pursue research careers in academia and some positions that are relatively declining in the last 20 years [3,6,7,8,9,10,11]. Beside academic positions, there are increased number of jobs in other fields, including advocacy, communication, community service, industry, social work and government, education. This complex ecosystem requires individual adaptability and “outside the box” thinking, as well as better exposure to real world biomedical problems and applications [6,9,10,11,12,13,14,15, 16,17,18].

In this article, we particularly reflect on the need to reform biological/biomedical science teaching and education and the effective approaches and strategies that we have developed at Texas A&M University (TAMU) to improve biological/biomedical science teaching and learning, particularly in large class that is challenging.

2. THE NEED TO REFORM CURRENT BIOLOGICAL/BIOMEDICAL SCIENCE TEACHING AND EDUCATION

In recent years, there have been numerous calls to reform biological/biomedical science teaching and education worldwide [3,8,16,19,20,21].

Intensively packed curricula that have expeditions instructions are preferred at numerous institutions worldwide. These curriculum instructions prioritize comprehensive subject matter rather than offering more opportunities for training students in significant professional and personal skills, including critical thinking, active learning, and problem-solving skills, despite the importance of these skills [22,23,24,25]. Moreover, there are also some limitations on allowing students to visualize difficulty concepts, and the development of major professional and personal skills of students.

There are currently limited opportunities for students to expose to real-world biomedical/biological problems at different institutions and health science programs worldwide [21]. Moreover, several studies have shown that some students have an inherent desire for learning and understanding the world around them, and for this selected learner group abstract theory is sufficient to inspire interest. However, most students can learn much better if there is a real-world application to the knowledge being presented [26,27,28,29,30]. Despite their importance in biomedicine, little room is left for introducing students to real-world applications for biomedical theory. Therefore, the continuous exposure of biomedical/biological science students to real-world biomedical problems is increasingly required.

Furthermore, accruing many professional and personal skills, including critical thinking, active learning, and problem-solving skills, learning engagement, teamwork, organization, time management and organization, is also increasingly required for biomedical/biological science students worldwide. In sum, there is a great need for innovative biomedical science course teaching reform and development worldwide.

3. APPROACHES TO IMPROVE BIOMEDICAL/BIOLOGICAL SCIENCE TEACHING AND EDUCATION

There is a current need for teaching reform of the biomedical science education for the reasons described in section 2 above. To reform and improve biological/biomedical science education and learning, several biomedical institutions worldwide have recently reevaluated current

problems of the biomedical science education. Several approaches and methods could be used to reform biomedical/biological science education such as promoting student critical thinking, deep and active learning, professional skills, and ability to both solve problems and visualize concepts [22,23,25,31,32,33].

The following sections describe the effective approaches and strategies that we have developed at TAMU to improve biological/biomedical science teaching and learning, particularly in large class that is currently challenging.

3.1. Promoting a Civil Learning Environment in Biological/Biomedical Science Class

People who have more civility are those who learn how to live well and connect with other people and can self-express and communicate effectively [34]. The maintenance of an effective civility in class can help in establishing a more effective classroom climate. Civility is, therefore, critical for maintaining a “healthy” and more successful classroom [35], which will in turn lead to improving the learning skills, performance, and outcome of students.

Due to its significance role in improving student learning performance and outcome, we have implemented civility in my classroom at TAMU using various approaches and strategies. For example, we have built cultures in biological/biomedical science class that encourage and reward careful listening, consistent communication, and supportive teamwork among all students. To achieve this goal, we have included more information in the course syllabus about the expectations for respecting and listening carefully to all other students in class. In addition, we talk to students about respect, clear thinking, and teamwork in class.

Moreover, we enhanced a climate that promotes civility in biology/biomedicine classes at TAMU. As instructors, we always served as a role model of respect and civility to promote a climate of civility in class. For instance, as instructors, we demonstrated excellent and careful listening skills and both consistent and regular communication and modeling behaviors that we want to encourage our students to express in class and, generally in life. To achieve this goal at TAMU, we used respectful tones toward all students, colleagues, and staff. Importantly, we also corrected students who do not use these respectful tones in class. This correction will be both publicly and privately. In addition, we were clear in class that we do not tolerate vulgar language, disrespectful or rude behavior, abusive treatment of other students, bullying, physical taunting of other students, racism, sexist or ethnic slurs, or destructive competition between students in class. Finally, we further encouraged civility in class at TAMU by both setting the rules and demonstrating civil conduct. For example, we called student by their names and make sure that we pronounce their names correctly that had a positive impact on students’ learning and engagement in class.

We have also implemented other approaches to state the expectations and set a tone of positive respect for students in class, including sharing productive feedback, and encouraging mutual respect, careful listening, teamwork, and more civility among students. Moreover, we praised students who listen respectfully and attentively to each other, and who help their classmates. Indeed, both implementing these approaches and honoring these behaviors can also foster kindness, and generosity of spirit to other students, leading to enhancing civility in student life.

3.2. Planning an Effective Biology/Biomedicine Class Session and Checking for Student Understanding

As a road map, planning of an effective class session can help the instructor to know what

students need to learn and how to do that effectively [36,37]. In addition, proper planning of class session can increase student engagement and helps them meet the class learning objectives, and enhance their learning skills, performance, and outcome [36,37]. Therefore, to plan effective class sessions, we have implemented certain practices at TAMU in which we addressed 3 major components: describing clear learning objectives, designing proper learning/teaching activities, and planning effective strategies to check student learning and understanding. For instance, we always describe clear learning objectives that can help instructors to decide the most appropriate teaching/learning activities in TAMU class. These activities can also help to determine whether the learning objectives of biology/biomedicine class have been accomplished. In addition, sharing the lecture plan by writing a brief agenda in the PowerPoint lecture presentation and telling students explicitly what they will be learning and doing in class are other two approaches that we applied at TAMU. Interestingly, we found that both describing the lecture topics and learning objectives and planning the class session effectively can promote student engagement in class, and enhance their learning outcome and performance, in agreement with previous studies [36,37].

Developing and applying an effective introduction to biology/biomedicine class are also important. We usually started class with a real-life story, recent scientific achievement such as Nobel prize, historical event, or a question that grabs student attention and triggers their engagement from the beginning of the class. Asking related question(s) at the start of the lecture class can also help instructors to have an idea about the students' familiarity with the lecture topics, and a sense of what they should focus on in the lecture class. Moreover, better planning of the specific learning activities in the main body of the lecture class is essential. These activities include preparing and providing several different ways of explaining the teaching materials such as visuals, analogies, and real-life examples. This appealed to different learning styles of students at TAMU and helped to catch the attention of more students in biology/biomedicine class. Importantly, planning to manage the time near the end of the lecture session and going over the material covered in lecture class are a key to improve student learning. We achieved this goal at TAMU by summarizing the main points of the lecture contents; either by stating the main points or by asking students to participate in summarizing these points.

Certain methods can be used to check and measure student understanding and knowledge in class. Using these methods should occur frequently and not only at the conclusion of a unit of instruction. Assessments are one type of several strategies that can be used in class to make sure every student is on track. Huba and Freed [38] defined assessment as "the process of gathering and discussing information from multiple and diverse sources in order to develop a deep understanding of what students know, understand, and can do with their knowledge as a result of their educational experiences". Various assessment techniques can play essential roles in student learning when using the results of these assessments in improving subsequent student learning.

At TAMU, we implemented several practices related to effective assessment techniques to obtain responses from the entire class. For example, we always ask questions "on the fly" to biology/biomedicine students during the lecture time. This approach helped instructors to check whether students can define biological and biomedical terms, make connections, explain concepts, and answer questions. In addition, we frequently asked open-ended questions in class at TAMU, which is a preferred kind of questions since it requires a little more thought by students and can help them draw out where they really are when learning in class. Indeed, we found that this approach enhanced student participation, attention, and engagement in class, in agreement with previous reports on the benefits of open-ended questions [39,40].

Besides asking questions effectively, we used responses from students to inform instruction through different approaches, including the use of questions that align to the learning objectives of the teaching course, using some questions to address common biological/biomedical

misconceptions and adjusting the instructions using student responses. Moreover, we used educational technology, including iClickers, to check for student understanding and advised students to use tech tools such as Quizlet or Google forms to further show what they learn and know. We received positive feedback from students about these implemented practices, in agreement with published reports [38,41,42]. Indeed, these implemented practices have helped instructors at TAMU to teach effectively by both adjusting and improving their teaching method and instruction using student responses.

We are planning to implement several other practices and approaches to further check for student understanding and improve their learning performance and outcome at TAMU. For example, we will use minute paper approach by posing 1-2 questions in which students can identify and write within 2 minutes the most significant biological/biomedical things they learn from the lecture. These responses will help the instructor to determine whether students are successfully identifying the most important points of my lecture. In addition, we will use documented problem solution approaches by choosing 2-3 biological/biomedical science problems or case studies and asking students to write down all the steps they can take in solving these problems with an explanation of each step. These approaches are effective in assessing the problem-solving skills of students in class. Furthermore, we are planning to use another approach, student-generated test questions, two weeks before the lecture examination. The instructor will share a pre-prepared question guidelines with students and ask them to think deeply about these examples of questions that they expect to see in the examination and try to answer at home.

3.3. Use Small Groups to Promote Active Learning in Biological/Biomedical Science Class

Active engagements of students in the information processing can improve their learning [22,23,25]. Active learning can be achieved, for example, by having students learn from each other in small groups [31,43,44]. Indeed, students working in small groups appear more satisfied with their class, tend to learn more of what is taught, and retain what they learned longer than when the same content is presented in other instructional formats [43,44]. Since not any group activity can promote active learning, better design and management of group activity or assignment is needed to lead to effective collaborative and active learning [45].

At TAMU, we have used small group activities to promote student active learning and inclusion of biological/biomedical science courses. To implement small group learning activities, we randomly grouped students (Group A, B, C, D, E, F; each group has up to 5 students) at the beginning of class sessions. Each lecture class was structured into three segments, each was covered by one multiple choice question (MCQ). The discussion of each segment and its question took 15 min before moving to the next segment/question. Every 15 minutes of the lecture class, we paused teaching and asked students to work in their small groups to discuss their answers for the MCQ and everyone participated in this learning task. Sharing the answers between different student groups can increase the whole class discussion, making the lecture more student-centered and interactive. In addition, we used both teaching methods, which can foster active learning and welcome questions from students, and an effective tone to provide feedback to students. Moreover, we reduced lectures, which were condescending in substance or tone to allow more time for active learning activities.

We are currently, planning to use team-based learning, which is a process that aims to structure large classes at TAMU for enhancing student participation, engagement, and active learning [22]. Team-based learning approach is practically important in large class at TAMU since it is based on using pre-structured small groups and well-organized course-related activities and assessments that can maintain student engagement and active learning [22].

We implemented other practices at TAMU to enhance the outcome of using small groups in prompting active learning. These practices included using open-ended questions (the best questions for engaging student groups), phrasing course assignments to promote higher-order cognitive skills of students, and challenging students to engage in synthesizing evaluating, questioning, and analyzing the problem's assumptions, to promote higher-level thinking. In addition, we used iClicker- based pop quizzes to further encourage student attendance beside their roles in enhancing student active learning. The use of polling software in class, including Padlet, Sli.do, Polleverywhere, Mentimeter or Kahoot, which are adaptable to different electronic devices, can further prompts class discussion and enhances student engagement and active learning [22]. Moreover, we used think-pair-share strategy, which is particularly appropriate for large class teaching since it is easy to manage groups of two students [22,46]. Interestingly, the feedback and comments from TAMU students on the above-described implemented practices were positive.

3.4. Planning and Facilitating Effective Class Discussion in Biological/Biomedical Science

It is well reported that preparing effective strategies that help students to prepare for discussions and for collaborating with their peers and instructors can improve student learning performance and outcome [22,47,48] At TAMU, we effectively designed distributed questions on the course schedule. We used open-ended questions that can generate multiple student high responses. In class, students were asked to discuss their responses in pairs or small groups. We also applied Think-Pair-Share strategy, before having a whole class discussion in which students presented their ideas to the whole class. The feedback and comments from TAMU students on these implemented practices were positive.

To have more effective discussion in class at TAMU, we are planning to distribute questions on Canvas Learning Management System (LMS) and include a mix of open-ended questions, which normally generate multiple high student responses, and comprehension (closed) questions that have a limitation in the number of correct answer(s). We are also planning to assign readings (e.g., a short research article) before class, which can allow students to be familiar with topics that are controversial in class. Moreover, students were giving the opportunities to prepare some questions for the discussion and post them on the discussion board on Canvas LMS. These questions can be graded and have feedback to increase the deep thinking of students, as reported [49]. Furthermore, we are planning to establish informal collaborative-learning groups in class. Each student group will solve a problem or analyze a figure or an image before explaining it to the entire class. Specific roles such as spokesperson scribe, and taskmaster, will be assigned for students in each group so that each student knows his responsibility within his group.

To further warm a class up for a class-wide discussion and made the lecture more interactive and student-centered at TAMU, we are planning to implement more practices. For example, we are planning to use both Harkness discussion strategy, which is all about student ownership and student-led [50,51], and the fast-paced strategy, 4 Chair Fishbowl, which is more appropriate strategy for teaching large TAMU class since it can facilitate discussion in large groups, sharing different points of view, and discussion of controversial topics [22,52].

3.5. Providing Effective Feedback and Encouraging Better Notetaking in Biology/Biomedicine Class

Trial-and-error learning is required for the mastery of both the teaching content and of how to think [53]. Providing meaningful feedback to students can, therefore, remarkably improve their

learning skills, achievements, and outcome. In addition, feedback is important in improving student learning experience, and have remarkable effect in professionalizing teaching in universities and colleges [54,55]. At TAMU, we implemented selected practices to provide more effective feedback to biology/ biomedicine students. For example, we ensure that the feedback is specific to be more effective, including supplying students with specific information about what they are doing wrong or right. In addition, instead of using feedback like “great job”, we advised students on what they still need improvement, with several suggestions to improve and notes on the progress they made since the last feedback. This approach also helped to evaluate the change or improvement of student performance since the last time we assessed them. To make the feedback more effective, we prepared feedback that clearly address student advancement toward a goal by providing explanations on how the information students received will help them to progress toward their final goals.

Importantly, careful presentation of feedback to students is a key since the way feedback is presented can clearly have an impact on how it is received and, therefore, can either enhance or decrease student motivation [54,55,56]. In addition, we prepared more focused feedback on 3-5 points only that clearly need further improvement, and we explained the purpose of these feedback and ensured that students understand how this feedback are meant to help them compete against their own personal bests. Interestingly, students were involved in the feedback process. In addition, giving information to students about their methods of reading, study, searching for information, and answering questions can help them to improve their learning skills and outcomes. This will also help students to recognize mistakes and eventually develop strategies for tackling problems related to their learning.

Furthermore, we employed educational technologies to enhance the efficiency of our feedback. For instance, we used discussion boards to communicate with students and post the feedback. Feedback can also be sent to students using video or audio recording, and if necessary, using blogs, chats, or forums as well as online quizzes with automated feedback. The feedback from students on the above-described implemented practices were positive.

Previous studies showed that given immediate feedback to students can significantly enhance their learning performance, compared to students who received delayed feedback [57]. Therefore, we immediately gave the feedback to students and without any delay to make these feedback more effective. Indeed, students who received immediate feedback are clearly better able to comprehend the learning materials they had read, as previously reported [57]. We are also planning to further involve students in the feedback process by helping them use the feedback to improve their learning performance and outcomes.

Another support to students is encouraging and developing their notetaking skills. Several studies found that notetaking can help to focus student attention. Notetaking can also promote more thorough elaboration of ideas, encourages efforts to relate ideas and organize materials, and help students to process gained information more deeply [58,59,60,61,62,63]. At TAMU, we implemented several practices to help students to effectively take and use their notes. For instance, we clearly organized and outlined the lecture contents, both orally and visually. Since students usually record the lecture outline, we referred to this outline to highlight shifts in topic during the lecture. In addition, we used transition statements and signaling phrases, including "this is important," "you'll want to remember," "these differ in two important ways," "the second point is," or "next,..." during the lecture.

We also used a framework of lecture information at TAMU. We gave students a framework or schema for how to organize information in two patterns: sequence or classification (“sequence” in the human anatomy and physiology course to explain changes or phases of a biological

process, and “classification” as in animal kingdom classification in basic biology courses). Notably, these two patterns helped students contrast and compare the teaching materials for differences and similarities. Moreover, we sometimes tell students what to record in class, including examples of human diseases (case studies), sample problems, and the cases and/or questions that are discussed in class. The feedback and comments from students on the above-described implemented practices were generally positive.

Other approaches can also be used as effective notetaking techniques to improve student learning skills and outcomes. For example, we are planning to make more time for notetaking activities in my class and prepare a handout of the skeleton (framework) and key notes of my lecture for students. This will help with better using notetaking as a vehicle to think more deeply about the lecture contents. Since training students to take better notes and giving feedback on their notes are also important, we will implement these practices and advise students to compare their notes to the handout of the version of lecture notes after class. This comparison is essential for student success since poor or no notes may be the source of much of learning difficulties/ problems student might have [60,61,62]. Moreover, we will advise students to explain their notes to a student seated nearby and ask them to write their paraphrased explanation in their notes.

3.6. Embracing Diversity and Inclusion in Biological/Biomedical Science Class

Diversity includes many aspects that make us different, including age, ethnicity, race, socio-economic status, and gender. Diversity in the classroom help students to build critical thinking and improve their academic outcomes [64,65,66]. Maintenance of diversity in the classroom can also improve student social skills. Indeed, diversity in the classroom can help student development of social awareness that will eventually help them appreciate multiple perspectives and draw stronger conclusions [67]. In addition, students are more likely to feel safer, less bullied, and less lonely in the most diverse classrooms [64]. Therefore, at TAMU, we implemented several practices to promote diversity and inclusion in biology/biomedicine class. For example, we brought diversity into TAMU class, by including diverse teaching and learning materials that exposed students to materials which represent multiple and different perspectives and viewpoints. In addition, we encouraged students to identify multiple solutions to a biological/biomedicine problem, which allowed every student voice to be both heard and respected. This approach was effective in enhancing student participation, engagement, and teamwork, in which they worked together even if they had a different opinion.

We encouraged student participation and engagement in biology/biomedicine class by turning the lecture class into a dialogue between instructors and my students. In addition, we gave students opportunities to ask questions throughout the lecture class. Notably, motivating students to participate in class discussions helped them to add their unique perspective to the overall conversation. Moreover, we avoided using stereotypes and generalizations in both course content and class using different approaches. Students with different abilities exist in a diverse classroom. We, therefore, make the teaching materials, course contents and other aspects of classroom accessible to all students in class. Therefore, we created more inclusive environment for learning and fostered a growth mindset in class that helped to build a “healthier” environment for student learning.

Knowing class students well was also an important approach to further embrace diversity in class. Besides knowing student names, knowing where they came from, and both their culture and socio-economic status can help to build professional personal relationships with students, which further promote diversity in class. In addition, we are planning to create time for voice and reflection in biology/biomedicine class using different approaches that enable more opportunities for all students to actively participate. We will also seek feedback from students to gauge clearly

when their voices are not being heard, listen to what students share, and demonstrate respect for all student contributions. We will build these approaches into the course design, so they become synonymous with other class activities and materials.

3.7. Ensuring Equitable Access to Learning for all Biological/Biomedical Science Students

Both course activities [68] and assignments [69,70] have a remarkable impact on student perceptions of engagement and learning as well as academic performance. At TAMU, we have implemented some important practices such as course activities and assignments that maximize student learning in class using various approaches and strategies as follow. For example, we normally informed students about the course assignments early. In addition, we provide sufficient information about each assignment, including its goals, objectives, and related learning activities so that students know in advance the pedagogical purposes of this assignment. We have also created a flexible deadline for these course assignments. Moreover, we planned to create an online discussion forum (Discussion Board) on Canvas LMS where students can ask questions about their assignments, receive my comments, and share their thoughts with their peers.

We helped students to appreciate the significance of reading my formative feedback. For example, in Hullabaloo U class at TAMU, we provided feedback for the reflection reports and assignments. We advised students to carefully review the formative feedback since it can improve their performance in the future. Providing both writing and verbal feedback on student assignments using learning technologies can also help students to improve their learning skills and outcomes. Furthermore, providing large-print copies of teaching materials and assignments can particularly help students with various degrees of vision impairments. The comments from my students on these implemented activities and practices were positive.

Small groups or one-one meetings is another approach that we used to discuss each assignment goals, objectives and learning activities before posting them on Canvas LMS. In addition, one-one meetings can enable instructors to further assist students with clarifying, brainstorming, and polishing the assignment. In addition, we found that giving examples of typical exemplary assignments to students from past students and submissions, which were unique and exemplary, can help them to know what they are looking for and realize a range of possibilities. Asking students to help with revising the assignment is another approach that can prompt for the next time the instructor teaches the course. Students can also write down the advice that they prefer to give to future students for succeeding at these assignments. Moreover, developing ePortfolio program benefits students since it can be used for archiving drafts of student assignments and reflecting on specific assignments.

3.8. Boosting Student Persistence in Biological/Biomedical Science Class

In academia, persistence is student percentage, who return to college, while retention describes student percentage, who return to the same institution. Enhancing the retention and persistence of students is highly required, particularly with increasing the levels of student dissatisfaction and consequently decreased enrollments recently because of multiple reasons. For example, between 2020 and 2021, an increase of 3.6% was reported for students who left college without completing, while college enrollment dropped 8% between 2019 and 2022 in the USA [71]. Therefore, we have implemented some selected practices that are well-knowing to maximize student persistence and retention [71] in class at TAMU using various approaches and strategies. For example, we always encourage biology/biomedicine students in class and improve their motivation and persistence by describing role models and examples of success in science. In the first class and throughout the academic year, we described how two great scientists, Charles Darwen and Albert Einstein, faced a lot of challenges, how they

demonstrated their commitment to their desired goals, and how they invested the necessary time and effort to achieve success.

We also designed the teaching course to have one module covering each textbook chapter in three lectures. In the first lecture of each module (every week), we provided a road map of the week's module. This map was also called the module plan, which helped students to put the module content in context and to plan their work time more effectively. In addition, we improved student engagement in class using different approaches, including real-life cases and examples related to human diseases, which connect students to real-life applications of knowledge that is related to the biology, and anatomy and physiology courses. Moreover, sending messages of encouragement and support verbally or in written, particularly after examinations, is also important and students like it. Furthermore, we found that sending reminder announcements on Canvas LMS at the beginning and throughout the week can communicate our support and encouragement to TAMU students and help keep them on track, as previously reported [72].

Student assessments and comments on these implemented teaching practices were very positive, in agreement with previous reports showing the importance of role models, success stories, and campus programs aiming to increase student engagement in enhancing student retention and persistence in colleges. Furthermore, students need a continuous encouragement and to build relations with peers, student leaders, faculty staff, to maintain high levels of engagement in college [71].

At TAMU, we implemented other practices and approached to enhance student engagement and persistence. For example, we included "group work" to further facilitate the asking and answering of various student questions that were also available for review by all students. Assigning group work near the end of each class can help to summarize the class discussion. Indeed, group work is known to facilitate and improve student learning outcomes, performance and, consequently persistence [73]. Moreover, using Artificial Intelligence (AI) technology and other technologies in education, including AI-powered chatbots, predictive analytics, live chat, and two-way SMS can provide a platform that enhances student retention, persistence and engagement [74]. In addition, using software such as Concept3D software, which is easily accessible from cell phone, computer, or iPad, can provide technology solutions for both wayfinding burdens and reducing communication that normally cause so much stress to students, particularly the first-year students. This strategy can lead to improving student engage and retention during their college journey.

4. GENERAL DISCUSSION AND CONCLUSION

In this article, we have reflected on the current need for reforming biomedical/biological science education. We also described our recently developed practices and approaches at TAMU to boost the biomedical/biological science learning and teaching, particularly in large class, which is currently challenging.

At TAMU we found that fostering and honoring civil behavior and respectful attitudes in class using the described methods in section (3.1) have benefited biology/ biomedicine students since they improved the learning environment, promoted civic ideas among students, and set a pattern for professional behavior. In addition, enhancing civility in class increased the engagement of students, and both student-student and student-faculty interactions, in agreement with previous studies [35]. Indeed, well-established civility in the classroom can also enhance student professionalism and mutual respect and will make students open to feedback, leading to improving the learning skills, performance, and outcome of students [75]. However, there were several challenges in implanting the described practices and values at TAMU, particularly when

there are limited time and production requirements in class.

Student comments on the strategies and approaches that we implanted for planning an effective class session and checking for student understanding, presented in section (3.2), were positive. The positive impacts of these strategies and approaches were also evidenced by enhancing the engagement of students in class and their improved performance in lecture examinations, in agreement with previously published studies. Indeed, effective planning of class session can enhance student engagement and help them meet the class learning objectives. In addition, it can increase student learning skills, performance, and outcome [36,37]. Moreover, student engagement and performance can be enhanced by using both in-class activities, including discussions, video, and small group activities, and assignment methods such as oral, written, and projects, which can also improve student real-world problem-solving skills [76,77]. Similarly, the positive impacts of effective assessments/assignments on student education are well documented [41]. Furthermore, instructors who use classroom assignment and assessment techniques are helping students to meet the course objectives [42].

Student feedback and comments consistently included positive responses to the applications of practices to promote effective class discussion and active learning using small groups that we presented in class (described in sections 3.3 and 3.4). The improvement of student engagement, active learning and learning outcome in class at TAMU that occur after implementing these practices agree with previous research studies on the impact of small groups in promoting effective active learning [22]. Students working in small groups were more satisfied with their class, tend to learn more of what is taught, and retain what they learned longer than when the same content is presented in other instructional formats [43,44].

Indeed, several strategies can be used to promote student engagement [25,78], and both student performance in and attitudes about biology courses are improved after applying active learning and student-centered pedagogy [79,80,81]. Furthermore, implementing effective class discussions can improve student learning outcomes and skills (22,47,48).

Remarkably, the student-centered approaches to instruction that we adopted and applied to enhance opportunities for student engagement in TAMU class were successful in improving their learning skills and outcomes, in agreement with previous studies shown that student engagement in the learning process can enhance their focus, attention and critical thinking [82,83]. Indeed, engagement of students in class can promote their learning outcomes in the higher education context [83].

Our reported positive impacts of both effective feedback and notetaking skills on increasing student engagement, participation and learning outcomes described in section (3.5) agree with several previously published studies. Indeed, providing and using effective feedback in educational settings can enhance student motivation, help student reflect on what they have learned, and build on their existing knowledge [54,55,56]. Effective feedback can help set a path for students, connect students with future learning opportunities and direct student attention to areas that need further improvement and growth. In addition, effective feedback can notably engage students in some metacognitive strategies, including task planning, goal setting, and both reflection and monitoring that are necessary key skills for self-regulated learning [54,55,56].

Similarly, notetaking can help students to process gained information more deeply [58,59,60,61,62]. Indeed, poor or no notes may be the source of much of learning difficulties and problems student might have [60,61,62]. Interestingly, notetaking could encourage active learning and to prepare study materials as well as help the focus attention of students. Notetaking

can, therefore, help students to process gained information more deeply [58,59,60,61,62].

Finally, the implemented practices in this article related to embracing diversity and inclusion and ensuring equitable access to learning for all biological/biomedical science students (sections 3.6 and 3.7) received positive feedback and comments from students. This agrees with previous reports showing that students feel safer and less lonely in diverse classes with a reduced stereotyping [64]. Moreover, diversity in class helps students feel represented and included, leading to more participation in class activities. Furthermore, ensuring equitable access to learning activities had a positive impact on student learning, in agreement with previous reports showing that various course activities can develop and improve student learning skills, and course assignments allow students to practice the learning expected of them in a specific course, and feedback from instructors can help them make necessary adjustments [84,85].

LIST OF ABBREVIATIONS.

AI: Artificial Intelligence
LMS: Learning Management System
MCQ: multiple choice question
TAMU: Texas A&M University

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