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EXAMINING THE EFFECTS OF A CASE-STUDY CURRICULUM IN A DIVERSE UNDERGRADUATE STEM CLASSROOM

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by

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ABSTRACT

EXAMINING THE EFFECTS OF A CASE-STUDY CURRICULUM IN A DIVERSE UNDERGRADUATE STEM CLASSROOM

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Following years of widespread use in STEM graduate programs and medical school curriculums, case-study teaching has become increasingly popular in science education. Case-study curriculums allow students to actively participate in problem solving, develop analytical tools, and perform independent research.

Despite these benefits, many student candidates for scientific and medical professions are not exposed to problem-based learning (PBL) methods in their undergraduate education. The goal of this study is to show student learning outcomes are improved by utilizing case studies and original research in an undergraduate STEM course. This study also provided the opportunity to assess PBL efficacy in a diverse classroom setting, including students from underrepresented groups. These objectives were

accomplished through a redesign of the University of Texas at Arlington's Fall 2020 toxicology course and a comparative data analysis of surveys, a collection of demographic data, and an evaluation of a reflection assignment. The results of this study revealed an increase in student confidence regarding essential literary science and research skills, provided insight on the response of underrepresented ethnic groups to the curriculum, and supported the expectation that a case-study curriculum improves student outcomes. This study maintains the benefits of case-study teaching and contributes to the research dedicated to addressing ethnic disparities in STEM.

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CHAPTER 1

INTRODUCTION

The case-study teaching method promotes the development of analytical skills and engages students in problem-based learning. Such learning methods have been shown to improve problem solving ability, teamwork, intrinsic motivation, and self-directed study (Hmelo-Silver, 2004). Case studies present scientific content to students through a narrative, accompanied by questions and activities which facilitate group collaboration and critical thinking. This approach has been shown to improve critical-thinking skills, emphasize analysis techniques, and promote the application of complex concepts (Bonney, 2015). For students in STEM, case-study teaching has been shown to improve the ease of learning, enhance the depth of understanding, and foster an appreciation of the relevance of subject matter within students, therefore better preparing student candidates for careers in STEM (Cliff and Wright, 1996). Thus, case studies are one of the most effective ways to bring inquiry-based experiences to the classroom so that students are better prepared for postsecondary success (Keller, 2016).

Case-study curriculums have an established history in business schools, law schools, medical schools, and other graduate programs; however, the current body of science education research provides limited evidence that the use of published case studies effectively promote the fulfillment of essential learning objectives in undergraduate biology courses and other STEM classes (Bonney, 2015). PBL has been successfully implemented in a wide range of educational settings for more than 30 years. However, a

large majority of the studies concerning the success of PBL has been limited to gifted students or studies done on medical school classrooms (Walker et al., 2015). Thus, the goal of this study is to provide evidence that a case-study curriculum improves learning outcomes in a diverse, undergraduate STEM course through PBL methods and participation in original research. Furthermore, this study seeks to assess the effectiveness of PBL teaching in an ethnically diverse classroom setting, as many of the students attending the University of Texas at Arlington (UTA) and enrolled in this specific course are those from underrepresented groups in STEM.

UTA's toxicology course is typically taught in a conventional, lecture-based curriculum, in which students proceed through a series of concepts and facts to be memorized. In the Fall of 2020, the class was reimagined as a case-study course in which students would complete a series of modules designed to enhance teamwork and leadership through group projects and presentations. The field of toxicology encompasses a wide range of real-world issues, such as air and water pollution, ecosystem heath, pharmacology, and epidemiology. Incorporating case studies addressing these complex issues give students the opportunity to work with real data and develop solutions to tangible issues. Many pre-health students who are historically focused on human-centered content are enrolled in toxicology courses. UTA's Fall 2020 toxicology course was no exception to this as approximately 71% of the students enrolled in the course indicated their intention to pursue health related careers. This course's emphasis on the interdisciplinary aspects of toxicology encourages students to understand the significance of organism-environment relationships which highlight the importance of ecological principles. This holistic and engaging teaching method is meant to encourage students to draw on multiple knowledge

areas and various skills in order to solve a problem. Thus, updating the toxicology curriculum intended to improve student learning outcomes, increase preparedness for post-graduate programs and ultimately to more thoroughly equip STEM students for entry into the workforce.

At the start and conclusion of the course, a pre- and post- survey were collected to assess student confidence in various science literary and research skills. Demographic data of students were also collected. These data were coupled with performance evaluations and student reflection. In the analysis of these data, we tested for the significance of apparent increases in student confidence at the conclusion of the semester and thus the significant effects of the case-study curriculum on student learning. Additionally, we performed statistical analyses in order to measure the response of ethnically underrepresented students to the curriculum.

This study's emphasis on the effects of the curriculum on students from underrepresented ethnic groups stems from the ethnic disparities noted among college completers in STEM. Although students of all ethnicities and race enter into STEM programs at about the same rate on college campuses across the nation, Black and Latino students seem to leave STEM disciplines at nearly twice the rate White students leave STEM (Arnim, 2019). Specifically, 40% of Black students and 37% of Latino students switch out of STEM majors before earning a degree. One study found that 19% of White students declare a STEM major, compared to 20% and 18% of Latino students and Black students respectively. However, 58% of these White students earn their degree in STEM, compared to the 43% of Latino students and 34% of Black students who complete their degree in the same field (Hills, 2021). Consequently, STEM educators have been uniquely

challenged to meet the needs of increasingly diverse STEM classrooms. This is of particular importance in STEM disciplines due to the ethnic disparities among undergraduate students and students who eventually go on to secondary programs that produce candidates for various scientific and medical professions. Therefore, we intend to detect the particular effects of the case-study curriculum on students from underrepresented groups as they are exposed to teaching methods that encourage inclusivity and group collaboration. It is our hope that this research might contribute to the advocacy of case-study learning in undergraduate STEM education and provide evidence that these teaching methods improve the outcomes of minority students, thus improving retention rates for students of all backgrounds and ethnicities.

CHAPTER 2

LITERATURE REVIEW

Case-based curriculums have a long-standing story of success in medical classrooms and is often used to improve clinical reasoning skills and diagnostic accuracy in training medical professionals (Turk et al., 2019). A study of medical students using a case-based curriculum showed an increase in mastery of physiological concepts, as indicated by a pre- and post-intervention test. The curriculum significantly improved exam scores in pediatric dentistry students who outperformed their non-case-study counterparts by nearly 20% (Beech and Domer, 2002).

Although much of the literature surrounding case-study teaching methods is limited to medical school and business classrooms, there is certainly evidence of the success of this method in undergraduate classrooms. A study analyzing the effects of PBL in an undergraduate biology course found case studies are significantly more effective than other methods of content delivery (Bonney, 2015). Another study attempted to measure faculty perceptions of the benefits and challenges in using case studies to teach undergraduate science. This study found that instructors who implemented case studies into their curriculums reported an improvement in critical thinking, a readiness to make better connections across multiple content areas, a more solid grasp of the practical applications of core scientific concepts, and an ability to view various issues from multiple perspectives amongst their students (Yadav et al., 2007).

Therefore, case-study curriculums provide numerous benefits to STEM students: better understanding of material, improvements in written and oral communication skills, ability to apply learned concepts to real-world situations, increases in motivation and engagement in self-directed study.

2.1 Enhancing Understanding of Material

A case-study curriculum delivered to undergraduate biology students resulted in increased performance on examination questions related to numerous fundamental biological concepts such as chemical bonds, mitosis and meiosis, and DNA structure and replication (Bonney, 2015). This study concluded case studies should be considered the preferred teaching method for teaching a variety of subjects in science courses. A study analyzing the role of Information Theory (IT) in case-based learning found that encoding specificity—the learning transfer which occurs when a situation closely resembles the conditions in which it will be applied— was the "active ingredient" in case-study curriculums and proves to be a significant feature of contextual learning theory in case-based learning (Turk et al., 2019). This study found that a case-study curriculum improved procedural knowledge, as measured by students' competence in applying clinical reasoning skills. Furthermore, the results of this study identified increases in examination scores among the cohort of students exposed to a case-based blended learning program (Turk et al., 2019).

2.2 Improving Communication Skills

The aforementioned study on undergraduate biology students reported findings positively correlated with the increase in student perception of learning gains associated with written and oral communication skills (Bonney, 2015). Another study, comparing

case-study and traditional, lecture-based teaching, found that case studies are a more effective approach for teaching scientific oral communication skills (Noblitt et al., 2010). A study evaluating the benefits and challenges of case-study teaching indicated increases in mastery of content and higher participation rates in class discussions (Yandav, 2007).

2.3 Real-World Applications

The case-study approach to teaching has been proven to enhance students' abilities to connect learned concepts with real-world applications (Keller, 2016). A study on undergraduate biology students found that students improved in their ability to recognize connections between biological concepts and real-world applications of these ideas (Bonney, 2015). Additionally, case-study teaching methods have been found to facilitate interdisciplinary learning that can be used to emphasize the relationships between specific scientific topics and actual societal issues and applications (Herreid, 1994).

2.4 Increasing Motivation

Because case-study curriculums require active participation in a class, they improve levels of student motivation to participate in class activities, thus promoting learning and improving performance on assessments (Turk et al., 2019). A study examining the electronic delivery of case-study teaching found similar improvements in student motivation. This is extremely relevant to teaching methods developed in recent years and is applicable to our particular study as the majority of UTA's classes were moved online as a result of the COVID-19 pandemic. According to the study, electronic case-based learning (CBL) requires students to self-engage in the case-based discussion and activities (Turk et al., 2019). This is a desired outcome in STEM classrooms as training autonomous learning skills is necessary in order to foster a commitment to a career of learning.

2.5 Encouraging Inclusivity

A study focused on multiculturalism in a science classroom emphasized the importance of relationship building to combat potential issues arising from student estrangement. This study found instructors "teaching for student attention and engagement" were more successful in managing diversified classrooms (Tartwijk et al., 2009). Likewise, the study supported the notion of frequent peer interaction and good student-to-student relationships improved overall student success. A similar study found social integration was vital to obtaining student learning objectives in a multicultural science classroom. This study described multicultural classrooms as "complex systems" that must be navigated with particular attention to peer relationships and class dynamics. Additionally, this study found promoting intergroup relations amongst students—in student led projects, study groups, and peer discussions—significantly improved students' attitudes based on the multiculturalism norms they express (Abacioglu et al., 2019).

CHAPTER 3

METHODOLOGY

To evaluate the efficacy of the curriculum, data collection consisted of pre- and post-course surveys and an end of semester reflection assignment. Demographic data were also collected, namely information on ethnicity. The pre-and post- surveys asked students to rate their confidence on 15 science literature skills on a Likert Scale of 1 to 5, in which 1=no experience and 5=highly competent; could carry out task on own unassisted (Table 3.1).

Table 3.1: Skills that students were asked to rate in the pre- and post- survey, on a scale from 1 to 5.

1. Conducting searches for literature pertinent to your research topic
2. Reading research articles
3. Interpreting research articles including results and findings
4. Interpreting visual representations of data (graphs, diagrams, tables)
5. Discussing research literature with a team or group
6. Creating written or oral summaries of a research article
7. Using primary literature to support/explain your own scientific findings
8. Properly citing and paraphrasing primary literature
8. Developing your own research questions or hypotheses
9. Using basic research data techniques (e.g. data entry/management, pre-processing, sample size)
10. Using software to analyze data
11. Producing figures and tables of results
12. Writing up research methods
14. Writing up research results
15. Presenting/discussing experimental results with a team/group

The pre- and post-surveys were offered to the class at the start and conclusion of the semester, respectively. These surveys were presented to all 66 students enrolled in the course and collected from the 21 students that completed both the pre- and post-survey.

At the end of the semester, a final reflection assignment was administered to the class and completed by 61 students who responded to questions regarding their concerns and challenges in approaching the different case studies (Table 3.2). This assignment also asked students to indicate the most significant things they learned in completing the case studies, any new skills acquired or developed throughout the course, and what aspects of the case studies and research were personally motivating for them.

Table 3.2: Reflection questions for students upon completion of the course

1. Think back to the first case study on lead exposure in post-hurricane New Orleans. Going into it, what do you think was your a) biggest concern b) your biggest challenge?
2. Think about the second case study dealing with the mass dolphin die-off. What was a) your biggest challenge b) the most significant thing you learned by completing this case?
3. By the end of the course a) what new skills had you acquired or developed b) how will you use these skills in your future education and/or career c) why do you think this learning matters?
4. What aspects of the case studies and research did you find personally motivating? What aspects did you connect with? Why?

3.1 Data Analysis Methods

The confidence levels measured in the pre- and post-survey were analyzed in a series of box and whisker plots to compare the differing scores from the beginning and end of the course. All 15 of the skills were plotted and assessed for significant differences in confidence. The plots describing a substantial difference in confidence were analyzed further using a two-tail T test in order to confirm the statistical significance of the different scores observed in the pre- and post-survey. The skills proved to have statistically significant increases in confidence were used for further analysis to test for the potential effects the curriculum may have had on the various ethnic groups represented in the class.

To test whether the curriculum had an effect on a particular ethnic group in the classroom, we performed a repeated measures ANOVA with skill score as the dependent variable and ethnicity as a fixed effect. Only one respondent identified as Black/African American and one as Native American or Alaska Native so those data were eliminated from the analysis.

The responses to the final reflection assignment questions were evaluated for common themes in student concerns and perceived improvement in skills. Based on the feedback from students, percentages were calculated of students that voiced a particular concern about approaching case studies or noted an improvement in a certain skill after the course. Percentages were also calculated for students who reported different motivating factors that influenced their participation in the case studies and improved their performance in the course.

CHAPTER 4

RESULTS

A total of 66 students within the class completed the pre-survey for this course, while 29 students participated in the post-survey administered at the end of the semester. Of this student sample, a sum of 21 students completed both the pre- and the post-survey presented to them. The data provided by these 21 students was the primary subject of analysis for this study.

Of the 21 students who responded to both surveys, 42.85% identified as Hispanic or Latino, 23.81% as White, 23.81% as Asian, 0.05% as Black or African American, and 0.05% as Native American or Alaska Native (Figure 4.1). The demographic data also provided that 71.43% of the participating students identified as female while 28.57% identified as male.

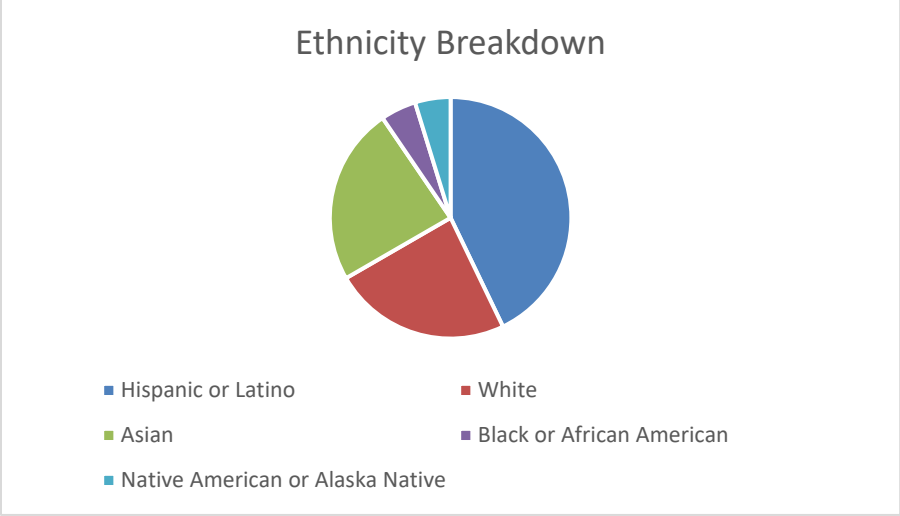

Figure 4.1: Ethnicity data for the toxicology students at UTA who participated in both surveys

4.1 Pre- and Post-Survey Results

The differences in pre- and post-survey scores indicated apparent increases in student confidence in performing various science research skills. The T-test conducted on the eight skills showing apparent increases in confidence revealed that four of these were significant at $P<0.05$ (Figure 4.2). The following skills showed statistically significant increases in confidence by the end of the course: interpreting research articles including results and figures ($P<0.001$), using primary literature to support/explain scientific findings ($P=0.010$), properly citing and paraphrasing primary literature ($P=0.047$), and writing up research results ($P=0.004$).

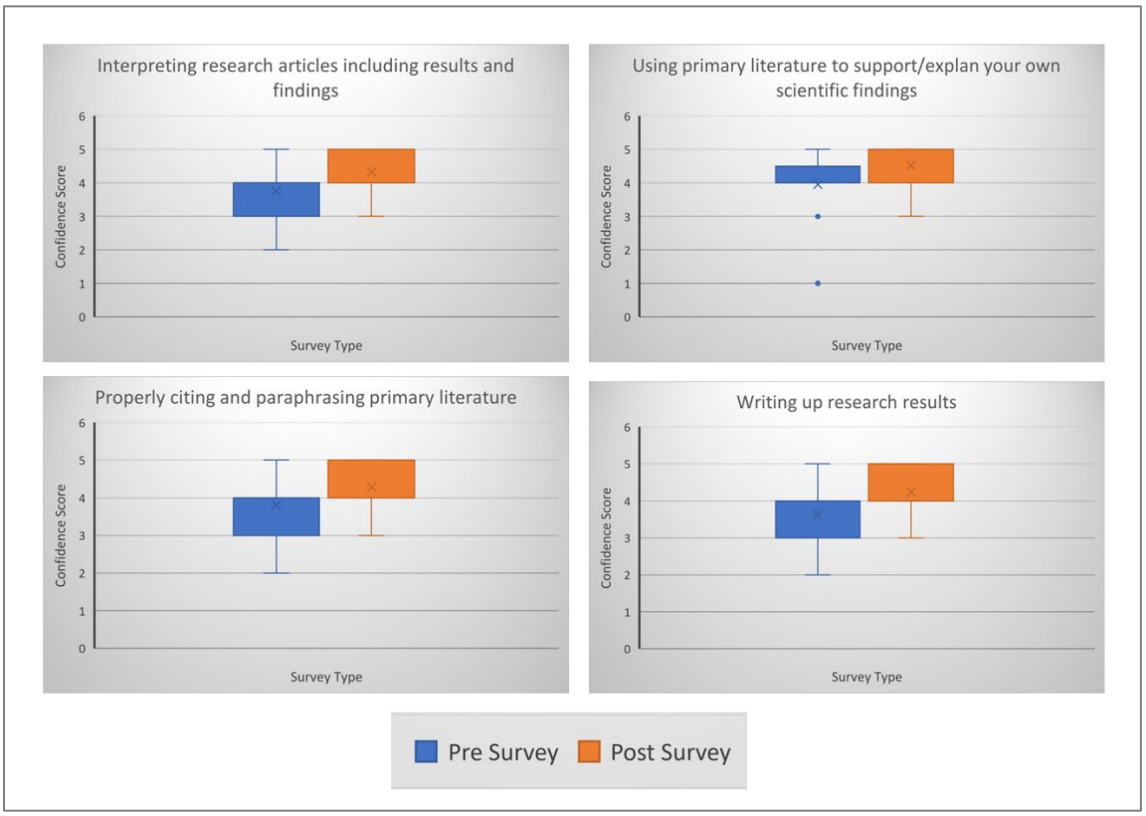

Figure 4.2: Statistically significant increases in confidence shown in comparative box and whisker plots

4.2 Effects of Curriculum on Ethnic Groups

The ANOVA used to evaluate the response of ethnically underrepresented students indicated evidence of an effect of the curriculum on these student groups. There was a significant effect of the curriculum regarding ethnicity for at least one of the research skills: properly citing and paraphrasing primary literature. The ANOVA showed the post-scores on this particular skill were significantly higher for Hispanic/Latino students (P=0.007, Figure 4.3).

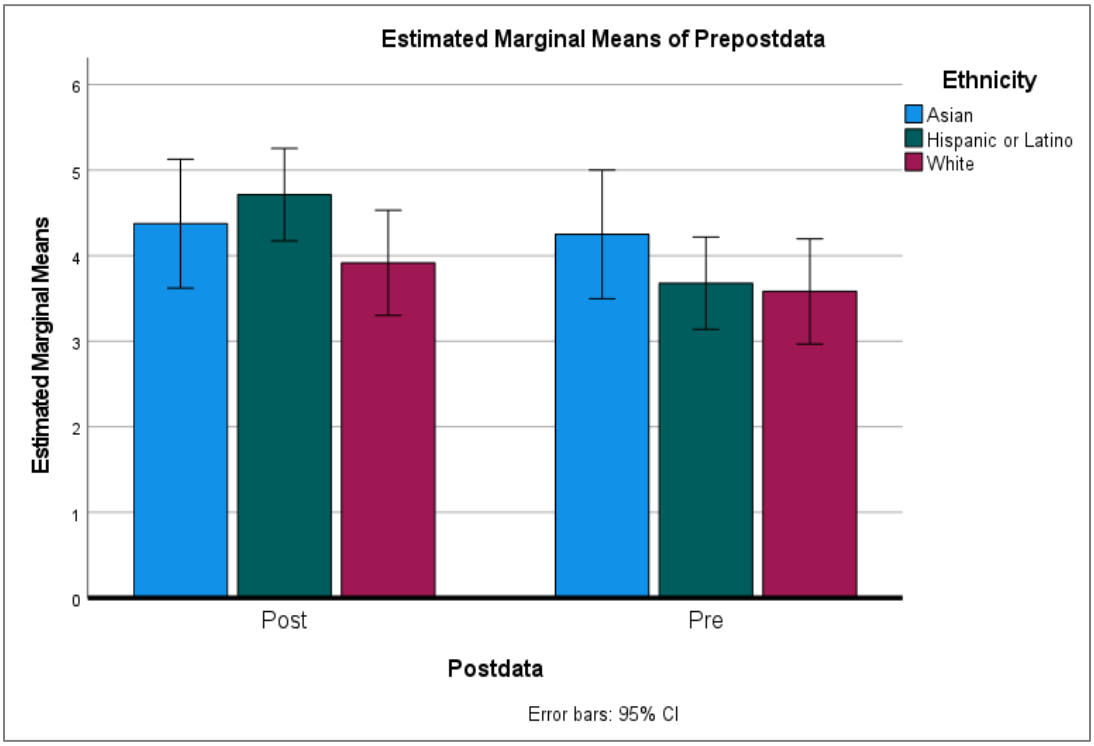

Figure 4.3: One-way ANOVA showing estimated marginal means of pre- and post-scores to determine effect of curriculum on different ethnic groups

4.3 Final Reflection Results

A total of 61 students completed the final reflection assignment. According to this feedback, 35% of students stated their biggest concern in taking a case-study course was their ability to find, interpret, and paraphrase primary literature. Subsequently, about 37%

of students reported a better understanding of this research skill by the end of the course. When asked about motivating factors in the course, approximately 44% of students reported that researching and proposing solutions for real-world issues was especially motivating in their participation and performance in the course. Additionally, 20% of students found that collaborating with their peers and participating in group projects was a motivating factor.

CHAPTER 5

DISCUSSION

The purpose of this study was to show case-study curriculums improve learning outcomes for students developing essential scientific research skills in a diverse, undergraduate STEM course. The collection of statistically significant increases in student confidence in this study support the expectation that a case-study curriculum enhances student learning objectives. The study also provided evidence that this case-study course positively affected students from underrepresented ethnic groups in at least one of the targeted skills for improvement, illustrating the benefits of this method of teaching in a diverse classroom.

The results of this study demonstrate a significant increase in student confidence in locating and interpreting primary literature, utilizing basic research data techniques, and improving scientific writing skills. These positive learning outcomes support the use of case studies to actively engage students in course content and to facilitate participation in independent research to develop science research skills.

The learning outcomes achieved in this study support the claim in which case-study teaching is among the most effective instructional strategies as it uses inquiry-based methods to connect course content with real-world applications (Keller, 2016). This study also provided evidence of improving intrinsic motivation within students, consistent with the previous research that reported case-study curriculums as an effective method for promoting student's motivation in STEM and thus improving retention rates of students in

STEM programs (Yalcinkaya, 2012). Overall, the results of this study illustrate an increase in student confidence as a result of their participation in independent research and group collaboration to solve real-world toxicology issues. Furthermore, this study provides support for case-study teaching as an effective process for producing participatory learning in the classroom. This participation facilitates active and reflective learning and results in improvements in critical thinking and effective problem-solving (Tomey, 2003). These skills are essential in developing self-directed lifelong learners who go on to pursue graduate programs and careers in STEM. Additionally, a study revealed that the delivery of electronic case-study teaching decreased burnout and disillusionment amongst students, providing further evidence that case-study teaching improves student retention rates in STEM (Turk et al., 2019).

A study examining the various ways to improve STEM retention rates for underrepresented minorities determined that an emphasis on science research skills and participation in original research improved the outcomes for minority students and increased the probability of these students attending graduate STEM programs (Estrada et al., 2016). The study also emphasized the importance of active learning and collaborative critical thinking as strategic methods in increasing the retention of ethnic minorities in STEM. Lastly, the study determined promoting individual creativity utilized in problem-solving exercises improved student outcomes, thus addressing ethnic disparities in STEM (Estrada et al., 2016). These teaching strategies are inherent to the case-study teaching method as students have the opportunity to engage in independent research, collaborate on ideas, and hone science research skills in these problem-based-learning courses.

Although this course and study demonstrated the positive impact of case-study teaching and provided evidence that the curriculum had a significant effect on an underrepresented ethnic group, it could have benefitted from a larger sample size. As the pre- and post-surveys were optional for students, only about a third of the data was viable for an accurate comparison of the impact of the course throughout the semester. Furthermore, within the sample size of the students that did participate in both surveys, there was a reduction in ethnic diversity compared to the class as a whole. This resulted in a limited analysis of the effect of the course on students from various ethnic groups. In future studies, a larger sample size with greater ethnic diversity would be preferable in order to produce more thorough results for the effects of the curriculum on these minority students. It should also be noted that the results of this study were impacted by the manifold variables in the education setting, including learning material, individual preparedness and varying difficulty of assigned tasks.

Toxicology is particularly conducive to interdisciplinary study and a case-study curriculum as it encompasses a wide range of issues facing local communities. Additionally, many of the students enrolled in this course indicated their intentions to pursue health related professions. Therefore, implementing a service-learning component to accompany the PBL nature of this course would allow students to utilize real data in their case-study investigations and encourage them to make an impact on their local community. Further research on the effects of a case-study curriculum with a service-learning component would be used to study the effects this course might have on student retention in STEM, particularly for underrepresented ethnic groups.

CHAPTER 6

CONCLUSION

Throughout this study, we analyzed an abundance of student feedback in order to assess the effects of this particular case-study curriculum and to draw conclusions regarding the changing confidence levels in performing scientific research skills amongst students of varying backgrounds and ethnicities. Our results provided us with a strong correlation of improvement in targeted skills and the case-study curriculum, particularly in skills such as interpreting research articles including results and figures, using primary literature to support/explain scientific findings, properly citing and paraphrasing primary literature, and writing up research results.

We were able to successfully record student improvement in these areas through a comparative analysis of confidence levels on a pre- and post-survey. Additionally, we detected a significant effect of the curriculum on students from underrepresented ethnic groups for at least one of our targeted skills. Accordingly, this study and curriculum structure contribute to the research in science education dedicated to bridging the gap between students in STEM disciplines. Finally, we collected a general reflection survey at the end of the semester which allowed students to express their feelings about the course. The majority of these responses reported a positive experience of the case-study curriculum and individual growth as student researchers, further contributing to the value of a case-study curriculum.

Conclusions drawn from this study are supported by previous research indicating the efficacy of case-study teaching in STEM classrooms. Further, the learning strategies implemented in this case-study curriculum are consistent with previously applied methods of promoting inclusivity, creative problem-solving, and critical thinking which have been supported to improve the outcomes of students that are underrepresented in the STEM field. Thus, is it our hope that this research contributes to the advocacy of case-study learning in undergraduate STEM education as these teaching methods have the potential to positively affect student outcomes and improve retention rates among minority students.

CHAPTER 7

REFLECTION

In a year wrought with unprecedented education challenges and the threat of a pandemic, it is no surprise this project was forced to evolve since its conception in the early Spring of 2020. Originally designed as an in-person, problem-based learning course with a service-learning component, this course had to be rapidly adapted in order to adhere to both university and CDC guidelines. Thus, the toxicology course was transferred entirely online, and the service-learning element postponed to the Fall of 2021. Despite these complications, the case-study curriculum was successfully implemented online, and we were able to gather sufficient data for our project.

The course of the study lasted for nearly a year, in which I had the pleasure to assist Dr. Walsh in preparing the content for this course, evaluating student performances and attitudes throughout the semester, and finally analyzing the data collected from the students. Throughout this process, I was challenged to see science education from a different perspective as I stepped out of a student role and attempted to understand the educator's point of view. This project provided me with a unique opportunity to work on research that intersected with my passion for science and students.

Throughout this project, I have acquired skills in data analysis and have developed a more thorough understanding of how to describe data in such a way that it tells a story about the subjects and content of the research. I was challenged to learn various data analysis techniques and to create accurate visual representations of the data collected in

this study. I also had the pleasure of reading through students' work throughout the semester and appreciating their growth as student researchers. In performing these tasks, I learned to evaluate assignments with discretion and gained an appreciation for the work done by STEM educators.

Overall, this project impacted my perspective of science education and inspired me to perhaps pursue a career in academia. Additionally, this study's focus on ethnic inequality in STEM classrooms provided me with the opportunity to perform research regarding ethnic disparities in education and develop a sense of advocacy for these issues. Lastly, this project allowed to me to evaluate my own undergraduate education and the teaching methods I have been exposed to throughout my career at UTA. Therefore, this project not only developed my growth as a researcher but also as a student and an advocate for equality.

REFERENCES

Abacioglu, C.S., Isvoranu, A., Verkuyten, M., Thijs, J., Epskamp, S. (2019). Exploring Multicultural classroom dynamics: A network analysis, *Elsevier J of School Psychology*, 74, 90-105.

Arnim, E. (2019, Oct. 8). *A third of minority students leave STEM majors. Here's why.* EAB.com. Retrieved from http://www.eab.com/insights/daily-briefing/student-succes.

Beech, D.J., Domer, F.R. (2002). Utility of the case-method approach for the integration of Clinical and basic science in surgical education. *J Cancer Educ.*, 17(3), 161-164.

Bonney, K. (2015). Case Study Teaching Methods Improves Student Performance and Perceptions of Learning Gains. *J Microbiol Biol Educ*, 16(1), 21-28.

Cliff, W.H., Wright, A.W. (1996). Directed case study method for teaching human anatomy and physiology. *Advances in Physiology Edu.*, 270(6), 19-28.

Estrada, M., Burnett, M., Campbell, A.G., Campbell, P.B., Denetclaw, W.F., Gutiérrez, C.G., Hurtado, S., John, G.H., Matsui, J., McGee, R., Okpodu, C.M., Robinson, T.J., Summers, M.F., Werner-Washburne M., & Zavala, M.E. (2016). Improving Underrepresented Minority Student Persistence in STEM. *CBE Life Sci. Edu.*, 15(3).

Herreid, C. F. (1994). Case Studies in Science—A Novel Method of Science Education. *J Col Sci Teach*, 23(4), 221-229.

Hmelo-Silver, C.E. (2004). Problem-based learning: What and how do students learn? *Educ. Psychol. Rev.*, 16, 235-266.

Keller, C. (2016). *Using STEM Case Studies to Prepare Today's Students for Tomorrow's Jobs*. 114th Partnership.

Noblitt, L., Vance, D.E., & Smith, M.L. (2010). A Comparison of Case Study and Traditional Teaching for Improvement of Oral Communication and Critical-Thinking Skills. *J of Col Sci Teach.*, 39(5), 26-32.

Tartwijk, J., Brok, P., Veldman, I., & Wubbels, T. (2009). Teachers' practical knowledge about Classroom management in multicultural classrooms. *Elsevier Teaching and Teacher Edu.*, 25(3), 453-460.

Tomey, A.M. (2003). Learning with Cases. *J of Continuing Edu. in Nursing*, 34(1).

Turk, B., Ertl, S., Wong, G., Wadowski, P.P., & Löffler-Stastka, H. (2019). Does case-based blended-learning expedite the transfer of declarative knowledge to procedural knowledge in practice? *BMC Med Educ.*, 19, 447.

Walker, A.E., Leary, H., Hmelo-Silver, C. & Ertmer, P. (Eds.). (2015). *Essential readings in problem-based learning*. Purdue University Press, West Lafayette, IN.

Yadav, A., Lundeberg, M., DeSchryver, M., Dirkin, K., Schiller, N.A., Maier, K., & Herreid C.F. (2007). Teaching science with case studies: a national survey of faculty perceptions of the benefits and challenges of using cases. *J Col Sci Teach.*, 37(1), 34-38.

Yalcinkaya, E., Boz, Y., Erdur-Baker, Ö. (2012). Is case-based instruction effective in enhancing high school students' motivation toward chemistry? *Sci. Edu. Int.*, 23(2), 102-116.

BIOGRAPHICAL INFORMATION

Sarah Wolff graduates in the Spring of 2021 with an Honors Bachelor of Science in Biology and a Bachelor of Arts in English Literature and Language, with a minor in Spanish. She has been a member of UTA's Honors College for four years and has served as a member of the Honors College Executive Board and as a Lead Advocate. Upon graduation, Sarah hopes to study and teach abroad in Spain, where she has accepted an English teaching position. Sarah hopes to attend a graduate program in the future but is currently undecided on her area of study.