Interdisciplinary Student-Centric Learning Approach for Undergraduate Engineering Students

Devina Jaiswal[1,*], Hillary Bucs[2], Madison Jakielaszek[1] and Leah Mikkelson[1]
1. Department of Biomedical Engineering, 2. Department of Communication, Media and The Arts
Western New England University, Springfield, Massachusetts, USA

*Corresponding Author: devina.jaiswal@wne.edu, ORCID:0000-0003-1699-2043

Abstract*— *This innovative practice work-in-progress study focuses on creating an interdisciplinary student-centric learning environment for undergraduate engineering students. **Student centric learning (SCL) technique requires students to take responsibility of their learning by indulging in creative activities that inculcates deeper learning. Such a learning strategy deviates from the conventional lecture technique which relies on one learning strategy fits all. SCL allows students to learn at their own pace through independent research, group work and discussions with instructors as well as peers. In this study, an engineering and a theatre professor collaborated to create an SCL anatomy module for undergraduate engineering students. Students were asked to implement a creative methodology such as sketch, quiz, storytelling or animation to teach an assigned topic in anatomy. The students were given an initial 50 mins introduction on storytelling by the theatre professor. Students worked in groups to, first, self-teach the topic and then, create a 20 mins lesson for their peers using a creative method of their choice. The creative method showed significant improvement in technical learning compared to control case (conventional lecture). In addition, students also perceived improvement in their collaborative skills and connection skills. Students showed high level of creativity while keeping learning at the center of each activity. Peer evaluation of the activities determined that out of the box ideas such as animation with voice-over and storytelling sketch were scored highest. In the future, deep learning assessment will be conducted by comparing scores from exam questions.**

Keywords—Student-centric learning, Anatomy, undergraduate, active learning

I. INTRODUCTION

Engineering education has evolved from behaviorism to cognitivism since the twentieth century [1]. Cognitive learning techniques require active engagement of the learner in acquiring and assimilating knowledge [2]. Professors are recommended to adopt techniques such as problem-based learning, discovery education, and flipped classrooms to promote long-term learning in undergraduate engineering courses [3, 4, 5]. These are student-centric learning (SCL) techniques where students drive the learning process. SCL techniques promote self and peer learning, in depth research of subject matter while students set the pace of the activities and learning [6, 7]. Mostly, students work in groups and the instructor acquires a supervisory role of providing the resources and support needed to develop an independent critical thinking to solve a problem [8]. These low-stress learning approaches enhance creative, communication, and collaborative skills of the students as well as improves their interaction with the instructor [9]. However, instructors have shown resistance towards application of such techniques because of lack of time or feeling the pressure of completing the syllabus [10, 11]. This hesitance ends up in implementation of teacher-centric techniques such as note-taking, listening to lectures, or observing power-point slides. Such passive behaviorism focused strategies result in students' mind to drift off in the middle of the lecture and are ineffective in providing deep learning. Professors are rethinking the passive teaching methodology specifically for topics that have been taught in lecture format for years. For example, anatomy and physiology (A&P) is a required course for health majors. Studies implementing a flipped classroom have shown an improvement in exam scores and better learning experience [12]. Allied health students have shown 12.9% improvement in exam scores after their lecture-based class was modified into a flipped classroom [13]. Other active learning techniques such as visual image-based learning has been proven to be more effective than textual learning by students in A&P classes [14]. A student-centric creative activity implemented for medical students has shown significant improvement in student learning after comprehensive assessment through exams and quizzes [15, 16]. These activities have been implemented in health majors where A&P is an important course, and its understanding cannot be undermined. Anatomy is also taught as a foundation lecture topic to the biomedical engineering (BME) undergraduates before they delve deeper into their major. Even though it is a sub-section of a full course, it is an important topic and there is a need to teach it using SCL methods. In this study, the goal was to create an interactive SCL activity, in collaboration with a theatre professor in the Department of Communications, Media and the Arts, to teach anatomy to BME sophomores. Here, we hypothesized that learning increases significantly after implementation of a student-centric learning approach. To accomplish the goal, a control lecture-based case was compared with creative-SCL case for the same group of students. Student technical knowledge and perception of skill improvement was evaluated.

II. MODULE EXECUTION

The interdisciplinary module was developed for a core course titled 'Foundations in Biomedical Engineering' for sophomores at Western New England University. The course introduces students to various fields of BME,

including basics of design concepts encountered in the field and anatomy.

Traditionally, anatomy was taught as a lecture with students filling in worksheets during the class. Based on student evaluations from Fall 2020, it was recognized that students felt disengaged during this section. This resulted in rethinking the method of teaching anatomy to engineering students in collaboration with the theatre professor. A class of 20 students was divided into 10 groups (2 students per group). Each group was given anatomical parts related to an organ system. The details of topic assignments are given in Table 1. Students were asked to think about a creative way of teaching the topic to their peers. Creative fields suggested to the students included but were not limited to song, sketch, story, puppet show and quiz. The work was accomplished in three stages: (1) online introduction to theatre and story-telling, (2) one-month check-in and (3) final class presentation.

A. Control Lecture-based Case

The work was divided into a control lecture-based and creative-SCL-based lesson plan. The first introductory topic, 'Anatomical relationships' was taught as a lecture by the instructor. Students were given fill-in worksheets that they completed along with the lecture.

Table 1: Distribution of anatomical parts based on organ system assigned to each group.

Organ System	Anatomical Structure
Skeletal System	Axial Skeleton: Skull, rib cage, vertebral column, gliding joint, pivot joint
	Appendicular Skeleton: femur, Patella, Ball socket joint, Tibia, Fibula
	Hinge joint, Humerus, Radius, Ulna, saddle joint
Muscular system	Rotator cuff, Bicep, Triceps, Gastrocnemius
Cardiovascular system	Heart (chambers of heart), Vena Cava, Aorta, Pulmonary Vein and artery, coronary artery
	SA, AV node, Purkinje Fibers, Bundle Branches
Nervous System	Central Nervous System: Brain: cerebrum, Cerebellum, Diencephalon, Brainstem
	Spine: Cervical, Thoracic, Lumbar, Sacral
	Cerebrum: Frontal, Parietal, Occipital, Temporal
	Peripheral nerves: Olfactory, Optic, Facial, Auditory

B. Creative-SCL Case

Stage I: Theatre Introduction

Theatre professor, Hillary Bucs, led an hour-long workshop on the introduction of storytelling for this stage. She began the session with an improvisational exercise, *Newscast*, to foster a creative and playful environment for the students by focusing on the skills of quick thinking and spontaneous content. The exercise was followed by an introduction to narrative structure based on the work of Keith Johnstone, the creator of *TheatreSports* [17]. The exercise, *Story Spine,* created by improviser Ken Addams, and coined by Applied Improvisation scholar, Kathy Koppet, focuses on group storytelling, one sentence at a time [18]. The objectives of the exercise were to illustrate the importance of such elements of story structure as *context*, *introduction of character*, *creating conflict*, *rising action*, *climax*, and *resolution*. Professor Bucs completed the session with connecting the elements of storytelling with the creation of sketches based on anatomy.

Stage II: One-month check-in

The check-inwas an online session with the theatre professor. Each group presented their idea in an informal format with the help of 1-2 power-point slides. Each group received a copious amount of feedback from both the professors. Students were advised to keep learning and creativity in their mind.

Stage III: Student presentations

Each group was given 25 minutes for presentation. In addition, groups were asked to create a worksheet of 10 questions for their peers as a study guide for exams. Creative activities presented by students included: animation video with voiceover (2 groups collaborated), choose your own adventure interactive game, interactive letter storytelling, sketch, jeopardy, Kahoot game and quiz (3 groups). Each group was given a rubric and they graded their peers after each activity.

III. ASSESSMENT

Student learning and perception of learned skills were assessed using an Institutional Review Board approved pre- and post-activity surveys. The survey consisted of 5-scale Likert type questions answered post module, pre- and post-technical questions (based on lecture and creative activity), and open-ended responses. The confidentiality of the participants was maintained by using a random number that was used to match the pre and post surveys. The Likert-scale questions were created to assess perception of knowledge retention, learning satisfaction, self-learning, communication and making connection between arts and engineering. The data was represented as mean±standard deviation. Two-Sample student's t-test with a significance level, $\alpha=0.05$ was used to compare control and creative activity data. In addition, peer rubric-based assessment was quantified to assess which creative method was perceived to be the most effective learning tool by the students.

IV. Results

The survey was taken by 10 out of 20 students (N= 10). The overall score on the technical questions was 38±18 % and 93±9% before and after the creative-SCL activity, respectively (p-value<0.005). However, the scores for pre- and post-technical questions for control lecture study showed no statistically significant difference with 1.2 times improvement in scores after the lecture. Figure 1A shows the comparison of perception of knowledge retention, learning satisfaction and degree of self-learning between control and creative-SCL study. Both learning satisfaction and self-learning was improved after creative-SCL module (p-value<0.05). Skills related to communication and connection between arts and engineering (Figure 1B, questions listed in Table 2) were rated more than 2.5 on the Likert scale by the students. Specifically, skills related to communication were rated more than 3 on the Likert scale. Figure 2 shows the average percentage score given by students to their peers while rating creativity and content-based learning after each activity. Methods such as animation, sketch and 'choose your adventure' were rated highly creative compared to quizzes and other quiz-based activities. However, all the activities were perceived to be 90% effective in helping students to learn the subject matter.

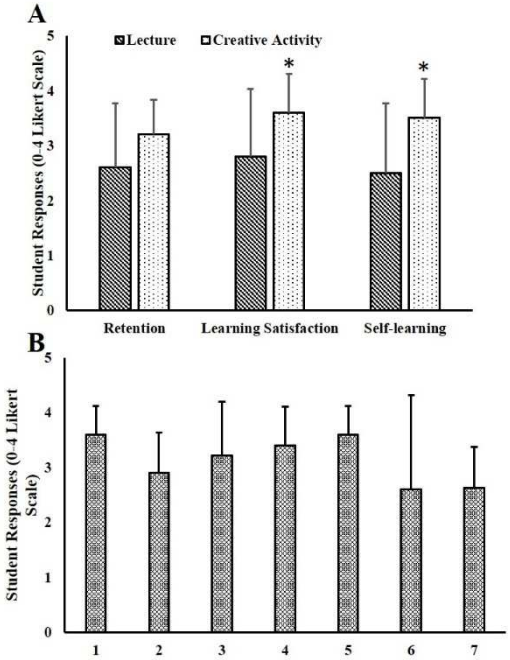

Figure 1: Students' perception of skill improvement was assessed using a post-activity survey. (A) Students perceived statistically significant improved learning satisfaction and self-learning ability after the creative activity compared to lecture-based classroom teaching. (B) Skills associated with collaboration and connection (description given in Table 2) received an average score of 3.1±0.8 out of 4.0 from the students after the creative activity. (* p-value <0.05)

V. Discussion

Student-centric learning (SCL) shifts the focus on students driving the content based on their research and learning pace. An instructor works as a guide who assists the students in accomplishing their activities. In this study, the SCL approach was applied to create an interdisciplinary learning environment. Though the basis of incorporating a medical theatre approach was the same as Singh et al. 2019

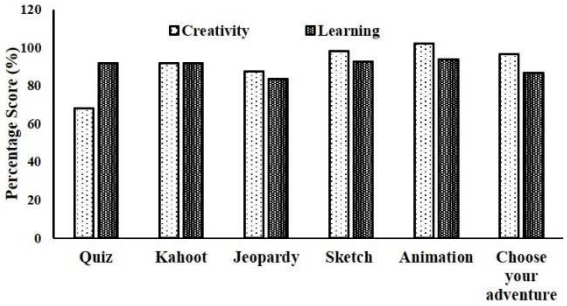

Figure 2: Average percentage score given by each group to their peers after their activity. The animation video scored highest in creativity and a comparable score associated with level of content-based learning after the activity.

and Diaz 2013 this work was novel for the engineering community [15, 16]. In addition, the work was conducted under the guidance of a theatre professor who inspired student work. The inclusion of an expert mentor created a strong creative foundation for engineering students and brought everyone to the same baseline before the commencement of the activity. Overall, technical questions showed an improved learning during creative-SCL work compared to the lecture-based approach. The result from pre- and post-technical questions for the control case showed a low impact on student learning. However, the creative-SCL approach motivated students to self-research the topic, connect it with a creative art form and effectively communicate the information to their peers. This can be seen from student comments, *"I got even better at having to teach myself", "I learned a lot from my own project"* and *"I felt I learned a lot*". The motivation to self-learn to prepare for the activity was highly impacted compared to lecture class as seen in Figure 1A. This can be

Table 2: Oral communication and connection-based skills evaluated after the creative activity.

	Oral Communication
1	Peer-Peer interaction skill
2	Comfort level in comprehending the subject using novel technique
3	Comfort level in presentation of subject matter using a mode other than PowerPoint
4	Visual aid helped in learning
5	Level of confidence in performance
	Connection
6	Application of arts to engineering course topic
7	Make connection between two disciplines

attributed to the nature of the creative activities that motivated students to excel in their presentation. As stated in student comments, "*Liked how creative and fun it was",* and *"It was a different type of project than we are used to as engineers".* About 90% of the groups indicated that they were happy with their choice of activity. This shows that students were confident about their work and perceived an improvement in their oral presentation skills as seen in Figure 1B. The students expressed, "*It was a new way to look at presentations", "learned presentation skills",* and *"better developed communication skills".* In addition, the interactive workshop gave students the confidence to create an innovative learning experience for their peers. The workshop and one-month check-in made the activity less challenging, and students became more passionate to learn. However, the level of knowledge retention did not show any significant improvement compared to the lecture. SCL approaches can generally create a highly interactive team-driven environment [19]. Though the focus of such an approach is to generate deeper learning, the work did not test long-term retention of knowledge. Students perceived that they retained the knowledge similarly for a lecture and a creative-SCL lesson. Within the creative activities, the most successful student work was the animation of heart anatomy. Based on Figure 2, out-of-the box ideas such as 'choose your own adventure', storytelling by role playing and animation were most successful among peers. The success of highly creative, story-driven activities validates the effectiveness of the theatre workshop. Since the engineering students were attempting to do something new, a few glitches such as technical issues or a wrong link to answers in 'choose your own adventure' impacted the learning. Students responded positively to familiar activities such as Kahoot and jeopardy. Kahoot is a common platform used by K-12 teachers as well as by students during group studies [20]. Students' performance and activity selection was impacted by the workshop and one-month check-in with the theatre professor. For example, one group was inspired by an example of a comedy sketch from "Saturday Night Live" given during the workshop. The animation video consisted of students role-playing anatomical structures of the heart in a pirate story and creative storytelling consisted of two students playing pen-palls, each suffering from spine related pathologies. Here, the instructors were guides who assessed the feasibility of the idea and helped in refining the work for presentation.

VI. Conclusion

In conclusion, the interdisciplinary student-centric learning activity was successfully implemented in a core BME course for teaching anatomy to engineering undergraduate students. The hypothesis was supported as the creative learning activities significantly improved technical knowledge compared to the lecture-based control study. In addition, students also perceived improvement in their collaboration and connection skills. Most of the activities conducted by the students were highly creative and promoted self-learning. In the future, a second iteration of the work will be implemented. More detailed data with respect to long-term learning through exams and quizzes will be collected to further confirm the effectiveness of this work.

References

[1] K. Yilmaz, The cognitive perspective on learning: Its theoretical underpinnings and implications for classroom practices. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *84*(5), 204-212, 2011.

[2] S.B. Merriam, and L.M. Baumgartner, *Learning in adulthood: A comprehensive guide*. John Wiley & Sons, 2020.

[3] W. Hung, D.H. Jonassen, and R. Liu, Problem-based learning. *Handbook of research on educational communications and technology*, *3*(1), 485-506, 2008.

[4] L. Alfieri, P. J. Brooks, N.J. Aldrich, and H.R. Tenenbaum, Does discovery-based instruction enhance learning?. *Journal of educational psychology*, *103*(1), 1, 2011.

[5] B.B. Stone, Flip your classroom to increase active learning and student engagement. In *Proceedings from 28th Annual Conference on Distance Teaching & Learning, Madison, Wisconsin, USA, 2012*.

[6] J. Froyd, and N. Simpson, Student-centered learning addressing faculty questions about student centered learning. In *Course, Curriculum, Labor, and Improvement Conference, Washington DC*, Vol. 30, No. 11, pp. 1-11, 2008.

[7] T. Brush, and J. Saye, Implementation and evaluation of a student-centered learning unit: A case study. *Educational technology research and development*, *48*(3), 79-100, 2000.

[8] K. Overby, Student-centered learning. *Essai*, *9*(1), 32, 2011.

[9] G.B. Wright, Student-centered learning in higher education. *International journal of teaching and learning in higher education*, *23*(1), 92-97, 2011.

[10] C. A. Estes, Promoting student-centered learning in experiential education. *Journal of Experiential Education*, *27*(2), 141-160, 2004.

[11] S. Pedersen, and M. Liu, Teachers' beliefs about issues in the implementation of a student-centered learning environment. *Educational Technology Research and Development*, *51*(2), 57-76, 2003.

[12] M., Entezari, & M. Javdan, Active Learning and Flipped Classroom, Hand in Hand Approach to Improve Students Learning in Human Anatomy and Physiology. *International Journal of Higher Education*, *5*(4), 222-231, 2016.

[13] M. A. Zimanyi, N. F. Emtage, & P. L. Megaw, Redesigning first year anatomy and physiology subjects for allied health students: Impact of active learning strategies. *International Journal of Innovation in Science and Mathematics Education*, *27*(8), 2019.

[14] M. M. Gross, M. C. Wright, & O. S. Anderson, Effects of image-based and text-based active learning exercises on student examination performance in a musculoskeletal anatomy course. *Anatomical sciences education*, *10*(5), 444-455, 2017.

[15] C. Diaz, Innovation in anatomy teaching. In *Education in anatomical sciences* (pp. 155-173), 2013.

[16] K. Singh, A. Bharatha, B. Sa, O.P. Adams, and M.A.A. Majumder, Teaching anatomy using an active and engaging

learning strategy. *BMC Medical Education*, *19*(1), 1-8, 2019.
[17] K. Johnstone, and I. Wardle, I, *Impro: Improvisation and the theatre*. Routledge, 2012.
[18] K. Koppett, *Training to imagine: Practical improvisational theatre techniques for trainers and managers to enhance creativity, teamwork, leadership, and learning*. Stylus Publishing, LLC, 2013.
[19] R. Rezaee, and L. Mosalanejad, The effects of case-based team learning on students' learning, self regulation and self direction. *Global journal of health science*, *7*(4), 295, 2015.
[20] A. I. Wang, and R. Tahir, The effect of using Kahoot! for learning–A literature review. *Computers & Education*, *149*, 103818, 2020.