Increasing Student Motivation and Learning by Adopting the Experiment-Centric Pedagogy: A Case of Undergraduates in Biology

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Abstract

This study is focused on the adoption of an Experiment-Centric teaching approach to enhance students' learning, develop their critical thinking skills, and help students better understand the underlying concepts in Biology, thereby giving them a better comprehension of how these concepts may be applied in practice as well as facilitating their academic success.

Traditional and Experiment-centric teaching methods were used to instruct students in four Biology courses (BIO 101-W09 Introductory Biology for Non-Major, Bio 103 Introductory Biology for Nursing Major, BIO 109-001 Foundations in Biology, Diversity, and Organismal Systems and Bio 201. Anatomy and Physiology I) taken by first and second-year students. The sensor from a heart rate mobile app was used to conduct and monitor - experiments in Biology. On phone screens, the data gathered from these experiments were visualized in real-time.

To measure the key constructs associated with students' success (motivation, epistemic and perceptual curiosity, and self-efficacy), data collection was done pre-and post-implementation of the experiments using the Motivated Strategies for Learning Questionnaire (MSLQ) developed by Pintrich, Smith, García, and McKeachie, in 1991. Also, the Classroom Observation Protocol for Undergraduate STEM (COPUS) was employed to characterize the simultaneous activities of instructors and learners during class sessions. More so, students' understanding of the course and the application of knowledge gained were evaluated using signature assignments.

Data analysis was conducted using Statistical Package for Social Scientists (SPSS 25.0). This research carefully investigated the gender differences in students' motivation and learning at a 95% confidence level.

Keywords: Experiment-centric pedagogy, critical thinking, student motivation, student learning, COPUS (Classroom Observation Protocol for Undergraduate), STEM (Science, Technology, Engineering, and Mathematics).

INTRODUCTION

In recent years, the existing educational system has been increasingly criticized for its inability to foster students' learning and motivation. The Traditional pedagogy, which involves heavy lecturing with little or no student participation and expecting them to retain a lot of material, is no longer an effective method of instruction [1].To increase student learning and motivation, several universities are increasingly adopting a methodology that places a focus on experiments [2]. In the setting of a biology course, the purpose of this study is to examine the impact of adopting an Experiment-centric pedagogy on undergraduate students' learning and motivation. Motivation and learning are intertwined; to achieve either, one must be motivated, either intrinsically or extrinsically [3]. College students require motivation to improve their understanding of a subject or experiment. Enthusiasm for a subject is a prerequisite for learning, and learning is the acquisition of knowledge and expertise.

Experiment-centric pedagogy (ECP) is a hands-on pedagogy that utilizes inexpensive, safe, and portable electronic instrumentation systems in various learning settings (classroom or student laboratories) to engage students [4] effectively. This is a teaching strategy that emphasizes student experimentation and exploration, and this strategy has been proven to be successful in raising student achievement levels [5]. The impacts of this pedagogy on student learning and motivation are further examined in this study, as well as how it might be applied in the classroom to foster engagement and success.

LITERATURE REVIEW

Experiment-Centric Teaching Pedagogy

A teaching strategy called Experiment-centric pedagogy emphasizes experimentation and discovery over lecture-based instruction. This pedagogy has been demonstrated to be successful in engaging students, improving their knowledge and comprehension of the subject matter, as well as their interest in learning.

The Experiment-centric teaching pedagogy is an effective educational method that provides students with tangible experiences that aid in increasing engagement and motivation in the learning process [6]. This teaching method has been shown to improve student understanding of the material by providing students with engaging activities that require physical participation [7] which is extremely helpful because it then allows students to explore their interests and develop their knowledge in a more active and meaningful way [8]. Experiment-centric teaching pedagogy has been shown in studies to improve academic performance and foster more positive attitudes toward learning [9]. Furthermore, it has been shown and known to boost students' self-confidence and motivation to learn [10]).

By allowing students to actively participate in the learning process, hands-on teaching pedagogy has improved student learning and motivation [11][12]. It encourages students to take ownership of their learning and be creative, which leads to increased engagement with the content material [13]. It also aids in the breakdown and accessibility of complex concepts, allowing students to become more confident in their understanding and motivated to continue learning [14][15].

Student Motivation and Learning

Recent studies have demonstrated that Experiment-Centric Pedagogy has a positive effect on undergraduate students' learning and motivation in biology as one of these studies conducted [16] found that students who received Experiment-Centric form of instruction scored higher on tests of scientific knowledge than those who received Traditional lecture-based instruction. The authors also found that Experiment-Centric Pedagogy increased students' motivation to learn, with students reporting greater interest in the subject and greater self-efficacy when compared to students in the Traditional lecture-based instruction group.

Similarly, a study conducted by Zhang X., et al 2019 [17] found that Experiment-Centric Pedagogy was effective in increasing students' knowledge and understanding of Biology topics, as well as their interest in the subject. In addition to studies that have investigated the impact of Experiment-Centric Pedagogy on student learning and motivation in biology, other studies have examined the role of student engagement in this type of teaching approach. In another study, it was found that students who received Experiment-Centric Pedagogy were more engaged in their learning and had a higher level of understanding of the content than those in the traditional instruction group [18]. The authors also found that student engagement was positively associated with increased motivation and learning outcomes. Finally, a recent study conducted by Li, M. et al [19] looked at the impact of Experiment-Centric Pedagogy on students' attitudes toward learning concepts in Biology. The authors found that Experiment-centric pedagogy was associated with increased interest in the subject, higher levels of knowledge, and are more enthusiastic to learn by showing positive attitude toward the subject. The authors also found that Experiment-Centric Pedagogy was effective in motivating students to learn, with students reporting higher levels of intrinsic motivation than those in the Traditional instruction group.

Gender-based Differences in Learning and Motivation

In educational settings, one of the most powerful social determinants of learning and motivation is gender [20]. Because gender is such a principal factor in learning, it is critical to comprehend how it influences student performance. For this paper, two main constructs are outlined and considered (1) Gender-based Differences in Academic Performance; (2) Gender-based Differences in Motivation.

Gender-based Differences in Academic Performance

Studies have found that gender is associated with academic achievement in biology. Girls are more likely to achieve higher grades than boys in the sciences, particularly in biology [21][22]. Girls are also more likely to take advanced biology classes compared to boys [22]. Additionally, girls are more likely to persist in their studies of science and biology than boys [23].

Gender-based Differences in Motivation

Studies have found that gender is a significant factor in student motivation in biology classrooms. Girls are more likely to be intrinsically motivated than boys, particularly when it comes to topics that are traditionally seen as "female" such as biology [24]. Additionally, boys are more likely to be extrinsically motivated than girls, particularly when it comes to topics that are traditionally seen as "male" such as mathematics [18].

Another study investigated the gender-based difference in students' attitudes towards biology. This study found that girls had a more positive attitude towards the subject and were more likely to take an interest in it compared to boys. This could be because girls may have an innate interest in biology, or it could be because girls may be more likely to receive encouragement and support from teachers and parents [25].

Overall, it may be postulated that gender has a significant effect on student performance, learning strategies, and motivation in biology classrooms. Girls are more likely to achieve higher grades, use cooperative learning strategies, and be intrinsically motivated, while boys are more likely to engage in competition and challenging activities, use problem-solving strategies, and be extrinsically motivated. Understanding the effect of gender on student learning and motivation in classrooms is important to promote equity and improve performance in the Sciences.

THEORETICAL FRAMEWORK

Learning is a dynamic and individual process. It is critical for educators to understand how new skills are developed, new knowledge is acquired, and new behaviors, morals, attitudes, and values are instilled. Learning theories describe the structure of how people learn. Research has been conducted to discover how people learn, and theorists have developed various theories on how learning occurs.

1. Self-Determination Theory (SDT): SDT is a macro-theory that proposes people are motivated by three intrinsic needs: autonomy, relatedness, and competence. The theory posits that when these needs are met, individuals will be more likely to be engaged and motivated in their activities [26].
2. Engagement Theory: Engagement theory is a micro-theory that proposes student engagement can be measured through three different types of activities: behavioral (e.g., attentiveness, effort, work completion), emotional (e.g., interest, enthusiasm, motivation), and cognitive (e.g., reasoning, problem-solving, critical thinking) [27].

3. Constructivist Learning Theory: Constructivist learning theory proposes that learning is an active process that involves constructing new knowledge from prior knowledge and experiences. Specifically, the theory proposes that meaningful learning is achieved when students are actively engaged with the material and can make connections between prior knowledge and new knowledge [28].

Experiment-Centered Pedagogy integrates problem-based activities and constructivist instruction by allowing students to actively participate in the learning process by constructing new knowledge or understanding by building on their prior experiences and understanding. According to Constructivism, knowledge acquisition occurs amid four assumptions: (1) Learning entails active cognitive processing; (2) Learning is adaptive; (3) Learning is subjective rather than objective; and (4) Learning entails both social/cultural and individual processes.
These theoretical frameworks will be used to explore how an Experiment-Centric Pedagogy can enhance student motivation and learning in undergraduate biology students.

Research Questions

The research questions that guided the study are as follows: (1) Does the Experimental Centric Pedagogy (ECP) enhance student learning, and motivation in the field of Biology? (2) How does the gender difference affect a student's motivation and learning rate? (3) Does an Experimental Centric Pedagogy increase the engagement of undergraduate students in learning and lead to measurable and lasting learning results?

RESEARCH METHODOLOGY

To answer these questions, various experiments such as fermentation in plants, and heart rate experiments were explored that could be used to relate certain concepts of Biology to students in a way that they would be excited to learn about, and after careful review of these concepts, we came up with a way to help students better understand these using an easily accessible hands-on device. As a result, the rationale for implementing ECP in the Biology discipline. In the field of biology, critical and difficult-to-understand concepts where electronic instruments can be used to make scientific measurements in explaining principles guiding such concepts were identified.

Following the identification of these concepts, experiments utilizing electronic instruments were developed and implemented. The Motivated Strategies for Learning Questionnaire (MSLQ) was used to assess key constructs related to student success, such as motivation, epistemic and perceptual curiosity, and self-efficacy [29-30]. Student success was determined by the academic performance of students who received ECP doses in different classes and across genders. Furthermore, to effectively integrate ECP into the Biology Discipline, the fundamentals of ECP and the Classroom Observation Protocol were implemented.

Student participation in ECP was evaluated using the COPUS, or Classroom Observation Protocol for Undergraduate STEM, created by Smith et al. [31]. Additionally, COPUS was used to accurately describe how instructors and students were spending their time in the classroom. A pedagogically proven evaluation instrument, COPUS can also give teachers feedback on the efficiency of their teaching methods to pinpoint areas in need of professional growth. University professors can rely on classroom observation, which has 25 codes and only two categories ("What the students are doing" and "What the instructor is doing"). We assessed the students' levels of motivation and tried to investigate how motivation and learning differed between the genders represented. Surveys were used to gather information, and students in each of these classrooms were also personally observed.

Velasco et al. [32] also suggested using a bar chart to analyze the observation results. This bar chart will show the percentage of behaviors, calculated as percentages of 2-minute intervals in a class period during which individual behaviors are observed, as well as the percentage of codes describing the nature of interaction-coded intervals co-coded with codes for the nature of verbal interactions.

Each module's knowledge gain was assessed using a signature assignment that was administered before and after the module to ascertain how much knowledge had been gained. The capacity to design and carry out experiments or test hypotheses, analyze and interpret data, and apply scientific judgment to make conclusions were all skills that were developed into instruments to assess the attainment of student learning outcomes.

Table 1: Showing the number of students(n) that participated in classes where ECP was administered & the experiment performed

Semester, Year	**Experiment**	**Female**	**Male**	**Other**	**Total(n)**
Fall 2022	Heart Rate Experiment	88	7	1	96
		91.7%	**7.3%**	**1.0%**	**100.0%**

According to the data in Table 1 above, 96 students participated in the classrooms where ECP was implemented. 91.7% of the students that took part in the experiment were female, making up most of the population. These classes are a combination of different sections. Both Bio 103 and Bio 201 had two and three sections, respectively. In the beginning, 114 students responded to the post-survey, and about 175 students to the pre-survey. Following more data cleaning, 96 respondents from the pre-and post-survey were obtained.

Implementation of ECP in Classes

Phase 1: Data Collection

1.1 Pre-Test: A survey was administered to students enrolled in a biology course at the university to measure their current level of motivation and learning prior to the experiment-centric pedagogy intervention. This survey asks students to rate their level of motivation and learning on a 1-7 Likert scale, as well as include open-ended questions about their attitudes towards Biology courses and their experiences with Experiment-Centric Pedagogy.

1.2 Implementation: A special project (Effect of Exercise on Heart rate) based on Experiment-Centric Pedagogy was implemented in the biology course. This involved the use of hands-on activities and experiments in the classroom, as well as the use of digital resources (Azumio - Instant Heart Rate App) to complement the Traditional lecture-based instruction of the course. The students were shown in class how to download Azumio app on the cellphone and use it to correctly measure their heart rate and it was explained to them the reason for the difference in results observed in each set (especially after performing a 5-minute exercise) which included 6 measurements of heart rate. Students were later given the assignment to work on 5 more sets of this experiment and were taught how to analyze and interpret the data collected - this data would be later used by them to write a Lab report.

1.3 Post-Test: A second survey was administered to students enrolled in the course after the Experiment-Centric Pedagogy intervention. This survey was identical to the pre-test survey and was also used to measure student motivation and learning after the intervention.

Phase 2: Report

2.1 Lab Report: At the end of the semester, students were required to analyze the data collected from each set of the experiment, write and submit a report of the experiment. This report was used to grade the students' performance for the purpose of this paper.

A total of 96 students were involved in this experiment. The Lab activity provided an opportunity for each student to download the Azumio: Instant Heart Rate App (Figure 1) where they explored the measurement of the heart rate at rest and during exercise. Heart rate, which could also be replaced by pulse, is the number of times a person's heart beats per minute. A normal heart rate depends on the individual, age, body size, heart condition, whether the person is sitting or moving, medication use, and even air temperature. Emotions can even have an impact on a person's heart rate. For example, getting excited or scared can increase the heart rate. But most importantly, regular exercise over time lowers the heart rate by making heart muscles work more efficiently.

The students were allowed to work on this assignment in groups; however, all students were required to submit an individual report.

Fig 1: The Azumio App used to measure heart rate

Fig 2: Result of the heart rate measurement in one of the experiments

DISCUSSION AND RESULTS

Does the Experimental Centric Pedagogy (ECP) enhance student learning, and motivation in the field of Biology? (Table 2)

To measure the motivation of students who participated in the biology classes where ECP was implemented, we made use of the Motivated Strategies for Learning Questionnaire [30]. This included various questions that can be used to determine Critical thinking, Test Anxiety and amongst others, their Intrinsic Goal Orientation Level.

Table 2: Results of the Motivated Strategies for Learning Questionnaire Manual: Fall 2022

	Constructs					
	Mean		**SD**		**Δ**	**P-Val**
	Pre	**Post**	**Pre**	**Post**		
Intrinsic Goal	2.84	2.61	1.36	1.15	-0.23	0.14
Task Value*	2.05	2.47	1.37	1.11	0.41	0.02
Expectancy Component*	2.02	2.48	1.37	1.28	0.46	0.01
Test Anxiety	2.65	2.44	1.6	1.08	-0.21	0.23
Critical Thinking	3.06	2.79	1.36	1.14	-0.27	0.08
Metacognition	2.48	2.72	1.12	1.15	0.24	0.09
Peer Learning/ Collaboration*	3.92	3.02	1.74	1.31	-0.89	0.01

Constructs used:

(IGO-Intrinsic Goal Orientation, TV- Task Value*, EC-Expectancy Component*, TA-Test Anxiety, CT-Critical Thinking, MC-Metacognition, PLC-Peer Learning/Collaboration*, EGO-Extrinsic Goal Orientation, IEC-Interest Epistemic Curiosity Scale, DEC- Deprivation Epistemic Curiosity Scale) *** Statistically significant**

The responses gathered from the Motivated Strategies for Learning questionnaire show the difference between the level of motivation, anxiety, and critical thinking before and after the experiment was performed.

There is a clear direction towards the improvement of Task Value and Expectancy Component, as shown by the descriptive statistics of the pre- and post-test scores of the MLSQ and Curiosity scales in Table 2, which show a significant improvement in the students' Task Value scores (mean = 0.41; $p<0.05$) and Expectancy Component scores (mean = 0.46; $p<0.05$)

Results shows that the difference between the pre and post mean of these constructs; Intrinsic goal orientation, Task value, Expectancy component and Metacognition increased after they participated in the experiment whereas Test Anxiety reduced after the students were taught using ECP (mean = -0.21, test anxiety is expected to continuously decrease due to the intervention). This shows that the students are now confident in the biology concept they have learned.

As previously mentioned, Table 2's results provide the summary statistics (mean, standard deviation, and mean difference) as well as the p-values of paired t-tests of students' pre- and post-test scores for each MLSQ domain.

Other notable improvements in the domain were in students' Task value (subdomains: I am very interested in the content area of this course, I like the subject matter of this course, It is important for me to learn the course material in this class) and expectancy component (subdomains: I believe I will receive an excellent grade in this class, I expect to do well in this class, I am confident I can do an excellent job on the assignments and tests in this course). It is evident from the outcomes of these constructs that ECP has boosted student motivation and their comprehension of the complex and challenging concepts in Biology.

We also allowed the students to make comments in a section for open-ended response and below are some responses that show how motivated and instrumental the implementation of ECP was in these Biology Classrooms.

- I liked my experience. I have never used this app before, nor have I used the others. I was intrigued by how the back of my phone can scan my heart rate.

- In this class using Azumio has helped me succeed with topics that were challenging for me.

- I enjoyed using the online app to learn more about my body

- The experience I had was easy. The material was easy to use, and the directions were also easy to follow

- In the class, we used the Auzimu app on our phones to track our heart rates after certain activities that we did. I enjoyed seeing how my activities changed my heart rate.

How does the gender difference affect a student's motivation and learning rate?

An overall low level of motivation was observed among the gender spectrum as shown in Table 3 and Table 4. At the pre-test, male participants had the highest scores in the motivation subscales except (IGO, EGO, TA, EC, and TV) and females had the highest score in the learning strategies subscales. At the post-test, only one person who represented the undisclosed gender was observed to perform better than the male and female participants in the subscales except in TA, CT, and PLC. In summary, the result within the gender spectrum showed that there were no significant differences in the scores of the participants (p>0.05).

Table 3: Pre-test comparison of MSLQ scores within the gender spectrum

Pre-test	**Female**	**Male**	**Others**	**Chi-square**	***p*-value**
IGO	2.84	3.05	2.33	0.62	0.73
EGO	1.78	1.86	1.00	0.88	0.65
TV	2.08	2.19	1.33	0.27	0.88
EC	2.02	2.10	1.67	0.47	0.79
TA	2.65	3.21	1.0	2.38	0.31
CT	3.11	2.71	1.33	2.03	0.36
MC	2.50	2.57	1.75	0.6	0.74
PLC	4.05	2.76	1.67	5.78	0.06
IEC	1.88	1.74	1.0	2.7	0.26
DEC	2.43	2.34	1.6	1.62	0.45

Table 4: Post-test comparison of MSLQ scores within the gender spectrum

Post-test	Female	Male	Others	Chi-square	*p*-value
IGO	2.60	2.52	3.33	0.59	0.74
EGO	2.56	2.62	3.00	0.64	0.73
TV	2.47	2.29	2.67	0.45	0.80
EC	2.48	2.62	3.67	0.94	0.63
TA	2.40	3.00	2.50	1.43	0.49
CT	2.73	3.52	3.00	1.45	0.49
MC	2.66	3.04	3.75	1.59	0.45
PLC	3.03	3.1	1.67	1.18	0.55
IEC	2.08	2.03	3.2	2.16	0.34
DEC	2.20	2.11	2.6	0.68	0.71

Does Experimental Centric Pedagogy increase the engagement of undergraduate students in learning and lead to measurable and lasting learning results?

Figure 2: Shows students activity in a biology course (BIO 201) during the period of the experiment as measured using the COPUS Scale.

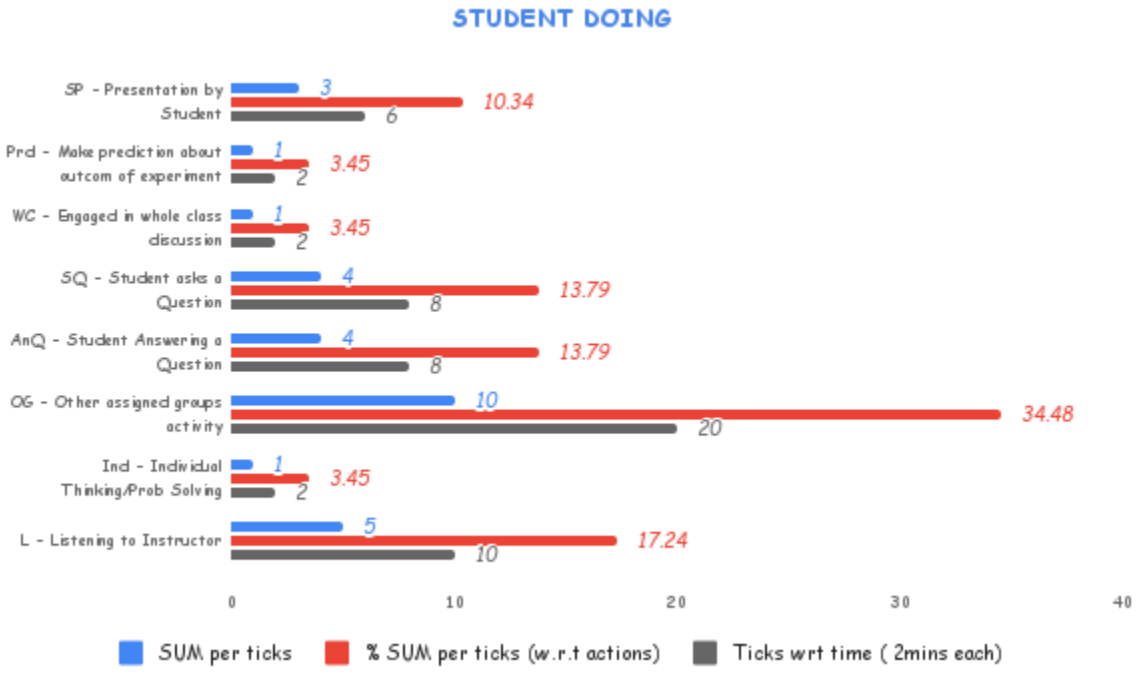
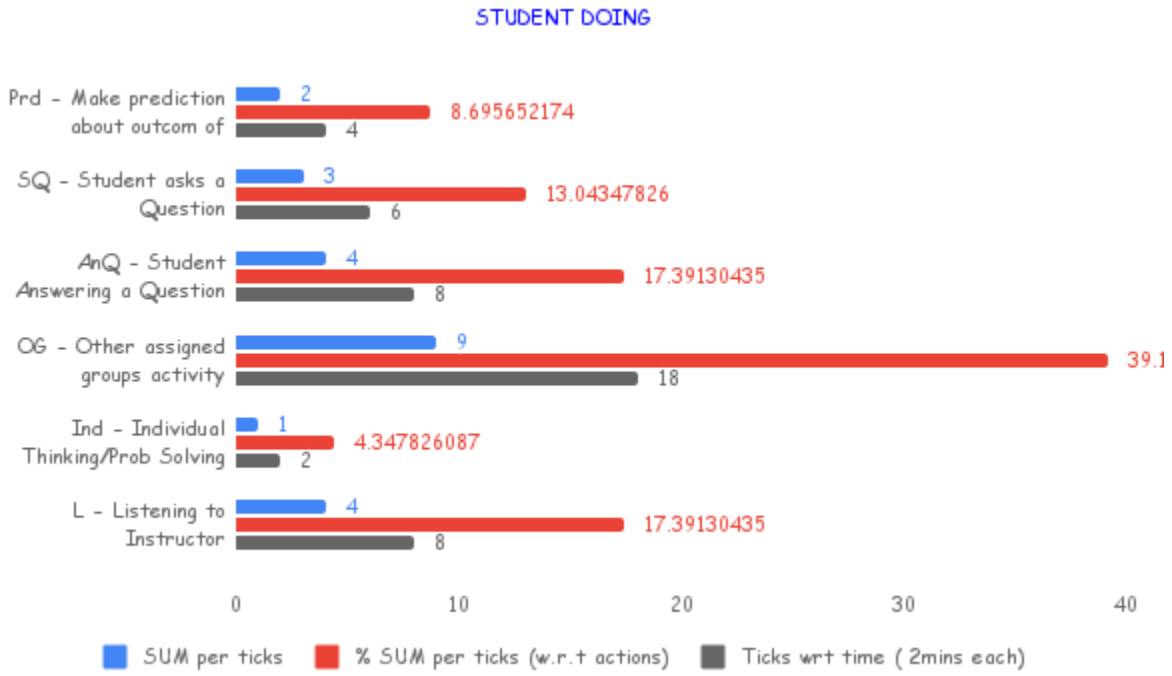


Figure 3: shows students activity in a biology course (BIO 103) during the period of the experiment as measured using the COPUS Scale.



Figures 2 and 3 above show the results gathered from the in-class observations using the COPUS with focus on what the students were doing during the experiment.

It can be deduced from our analysis that the students spent more time participating in the "Other Assigned" group activity which in this case is performing experiments. In each of these selected classes, 34.48% and 39.1% of the time, students were exploring and engaged in experimental learning respectively. They listened to the instructor and even before the experiment was performed, some of the students were able to make predictions about the result. Although not all predictions were right, it still shows that the students were motivated and displayed critical thinking skills while trying to make these predictions. To show their interest, the students asked questions to enable them to further understand the purpose and the process of the experiment. Some students after the experiment mentioned that they learned a lot and even so better understood the concept on which the experiment was built - which if it had been taught in a traditional classroom they might not have fully understood.

Implementation of this experiment can be said to have measurable and long-lasting results as some students who had taken similar experiment in a previous semester and took part in the experiment in the following semester, attested that experiment first before lecture helped them understand the

concepts taught better and they are able to recall better what was experimented than that which was just taught using the traditional method which is lecture before experiment.

CONCLUSION

To teach the concepts of heart rate, factors that affect heart rates, and the impact of heart rate on an individual's health, ECP has been devised, implemented, and evaluated at an American institution. ECP has been shown to increase students' motivation and success in meeting the stated learning objectives for topics in Biology, as expected. ECP also makes it easier for students to demonstrate that they have a better grasp of the expected competencies in the modules as results show that their Intrinsic goal orientation, Task value, Expectancy component and Metacognition increased after they participated in the experiment. The difference in the gender spectrum was also analyzed but due to the inappropriate proportion of the gender's involved in this study, we cannot make a conclusion on Gender-based differences in learning and motivation. We hope to expand our population size for further research in-order to ensure that there is a fair distribution of all participating genders.

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REFERENCE

[1] T. Bentley, and L. Miller, (2011). Traditional pedagogy versus constructivist pedagogy: A comparison of two instructional approaches. Journal of Instructional Psychology, 38(1), 33-41.
[2] L. Joseph, (2017). Experiential Learning in Higher Education: A Review and Call to Action. Educational Psychology Review, 29(3), 587-609. doi:10.1007/s10648-017-9411-8
[3] R. Ehrenberg, (2020). Motivation and Learning. In Encyclopedia of Educational Psychology (pp. 587-589). SAGE Publications.
[4] O. A. Owolabi, J. K. Ladeji-Osias, O. S. Alamu and K. A. Connor, "Global Impact of Experiment-Centric Pedagogy and Home-Based Hands-on Learning Workshop at a Historically Black University", Paper presented at 2021 ASEE Annual Conference & Exposition, Virtual Meeting, Paper ID 34049

[5] E. Hollenbeck, and C. Moore, (2016). An Exploration of Inquiry-Based Learning and Its Effectiveness on Student Achievement. International Journal of Research Studies in Education, 5(2), 55-68.
[6] K. Bukoski, (2017). Experiment-centric teaching pedagogy: An effective educational method. Journal of Educational Practice, 8(2), 81-86.
[7] P. Trujillo, (2015). Teaching methods for physical education. International Journal of Teaching and Education, 3(2), 1-7. doi:10.5897/IJTE2015.0224
[8] A. Murray, (2017). Exploring student interests in the classroom. Journal of Learning, 29(3), 41-45.
[9] R. Davis, (2019). Experiment-centric teaching pedagogy and its effect on student academic performance and attitude. Journal of Education and Learning, 8(2), 53-63.
[10] C. Chang, (2018). The Impact of Smartphone Applications on Students' Self-Confidence and Motivation in Learning. International Journal of Education and Learning, 4(3), 99–107. https://doi.org/10.26417/ijel.v4i3.p99-107
[11] C. Fischer, (2020). Hands-on teaching for improved student learning. Retrieved from https://www.teachthought.com/pedagogy/hands-on-teaching-for-improved-student-learning/
[12] J. Wheeler, (2013). The Benefits of Hands-On Learning. Retrieved from https://www.edutopia.org/blog/benefits-hands-on-learning-john-wheeler
[13] J. Reeve, and H. Jang, (2006). Self-determination theory applied to educational settings. In K. R. Wentzel & A. Wigfield (Eds.), Handbook of motivation in school (pp. 183-207). Mahwah, NJ: Lawrence Erlbaum.
[14] S. E. Kastberg, and B. Blevins-Knabe, (2015). The impact of hands-on teaching on student learning and motivation. International Journal of Education & the Arts, 16(25), 1-27.
[15] J. Holland, (2018). The Impact of Visual Learning on Students' Understanding and Motivation. Journal of Visual Literacy, 37(2), 89–105. doi:10.1080/1051144X.2018.1460240
[16] M. Siu, and M. Chen, (2018). The effects of experiment-centric instruction on scientific knowledge and motivation: Comparing lecture-based and experiment-based instruction. Journal of Science Education and Technology, 27(2), 311-321. doi:10.1007/s10956-017-9718-z
[17] X. Zhang, Y., Wang, and J. Li, (2019). The Effectiveness of Experiment-Centric Pedagogy on Students' Knowledge and Interest in Biology. International Journal of Education and Development, 7(1), 15-29.
[18] X. Zuo, Y., Zhang, J. Wu, and X. Zhang, (2017). Does experiment-centric teaching lead to higher student engagement and achievement in biology? Research in Science Education, 47(2), 301-316.
[19] M. Li, J. Brown, X. Han, and Y. Chen, (2020). The impact of experiment-centric pedagogy on students' attitudes toward biology. International Journal of Educational Research, 20, 101-113.
[20] H. J. Falk-Krzesinski, and G. E. Thomas, (2009). Gender and learning: Exploring the connections. In M. J. Furlong & M. L. Christenson (Eds.), Handbook of adolescent psychology: Individual bases of adolescent development (Vol. 2, pp. 531–563). Hoboken, NJ: Wiley.

[21] X. Guo, Y. Chen, and Y. Li, (2012). Gender differences in academic achievement in science and mathematics: A meta-analysis. Educational Psychology Review, 24(3), 241–258.
[22] P. C. Liou, (2018). Gender differences in academic achievement in science and mathematics: A meta-analysis. International Journal of Science Education, 40(7), 825–845.
[23] S. L. Beilock, E. A. Gunderson, G. Ramirez, and S. C. Levine, (2012). Female teachers' math anxiety affects girls' math achievement. Proceedings of the National Academy of Sciences, 109(20), 7841–7845.
[24] L.R. Ketterlin-Geller, (2012). Gender and Intrinsic Motivation in the Science Classroom: A Study of Student Interest in Biology. International Journal of Science Education, 34(8), 1145-1162. doi: 10.1080/09500693.2011.589399
[25] Y. Wang, (2018). Gender-Based Differences in Student Attitudes Toward Biology. International Journal of Education, 10(1), 50-62.
[26] E. L. Deci, and R. M. Ryan, (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological Inquiry, 11(4), 227-268.
[27] J. A. Fredricks, P. C., Blumenfeld, and A. H. Paris, (2004). School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74(1), 59-109.
[28] J. Piaget, (1977). The development of thought: Equilibration of cognitive structures. New York, NY: Viking Press.
[29] T. Garcia, and P.R. Pintrich, (1996). Assessing Students' Motivation and Learning Strategies in the Classroom Context: The Motivated Strategies for Learning Questionnaire;
[30] R. Taylor, (2012). Review of the motivated strategies for learning questionnaire (MSLQ) using reliability generalization techniques to assess scale reliability (Doctoral dissertation) Auburn University
[31] M. K., Smith, F. H., Jones, S. L., Gilbert, and C. E. Wieman, (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): A new instrument to characterize university STEM classroom practices. CBE—Life Sciences Education, 12(4), 618-627.
[32] J. B, Velasco, A. Knedeisen, D. Xue, T.L., Vickrey, M., Abebe, and M. Stains. (2016) "Characterizing Instructional Practices in the Laboratory: The Laboratory Observation Protocol for Undergraduate STEM". Journal of Chemical Education. Vol 93, pp 1191-1203