PBL vs LBL Instructional Methods in Teaching General Relativity in High School Physics Classrooms in the US.

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Introduction

Education gives humans the opportunity to contribute to our modern society by acquiring skills to do so. Education lays the foundation for our future and career paths. It helps us open us up to opportunities and enables us to explore our curiosities. For this reason, countless cultures around the world revere educators. Not only do Educators have to provide the tools for students to accomplish their goals, but also complete the strenuous process of motivating and coaching disinterested persons. In order to educate students effectively, educators have experimented and researched various methods for teaching. In the United States public education system, most teachers tend to use lecture based methods. Lecture-based learning (LBL) is a traditional teaching method, where an instructor delivers a verbal lesson while using a visual display such as a projector or whiteboard. Another method of teaching is known as problem/project-based learning, also known as PBL, where complex real world problems and projects promoting kinesthetic learning are used to present information instead of a direct depiction of concepts. There however, is no definitive perfect teaching method as each style of instruction caters to certain skills which may be more useful in certain topics than others. These two methods are regarded as effective teaching methods for most The primary objective of this research is to compare and contrast the effectiveness of the usage of PBL and LBL on student performance on a summative assessment, which measures understanding, specifically in physics classrooms on the lesson of general relativity in high schools. Additionally, this research also aims to find if preference between the two types of instruction plays a role in student performance. For example, if a student is taught by their preferred teaching method, will they perform better on the assessment than a student taught by a non-preferred method? This research will benefit high school physics instructors as they will be able to more effectively teach students the lesson of

general relativity. A significant difference in the performance of the students in this study would show the superiority of using a certain method of teaching when educating students on the lesson of general relativity.

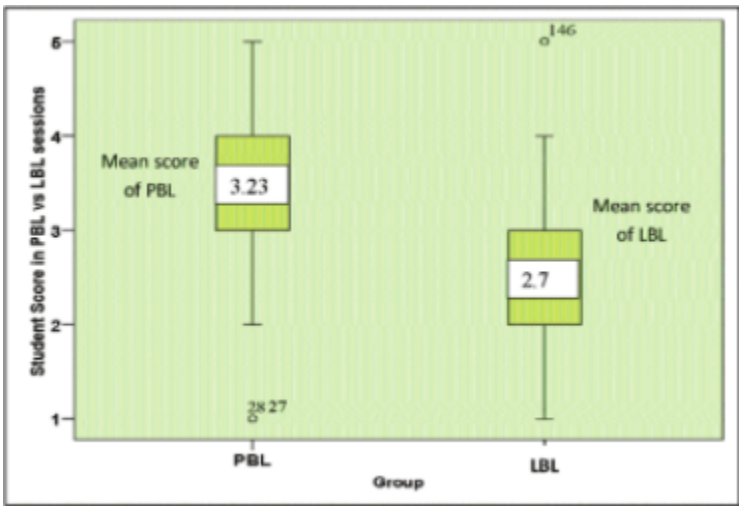
Literature Review

Evidently, PBL and LBL are reputed and popular methods of instruction all around the world. Hence, there is extensive research on the effectiveness of each method in specific lessons. Research in this field dives into the specific uses of each method yet there is a lack of research specifically focusing on the comparison of using lecture-based methods and problem-based methods in the lesson of general relativity in high school physics classrooms. In a journal article published by the National Science Teachers Association, Christine Chin shows a practical application of Problem-based instruction in order to promote project-based science which develops student's problem solving skills. She concluded that problem/project-based learning allows the classroom to transform into "active learning environments with a dynamic interplay of questioning, explaining, designing investigations, communicating ideas, collaborating, and reflecting" (Chen 2008)[1]. In her article, she investigates possible ways to promote project-based science in students and teach them to solve problems creatively. She used an experiment in which a group of 39 students used problem/project-based learning to learn several concepts. She found that PBL can be used very effectively as long as teachers help students by keeping them on track. Adding onto Chen's point of the effective implementation of problem/project-based learning, Erik De Graaff, a professor at the Delft University of Technology in the Netherlands, in his journal article "Characteristics of Problem-Based Learning" affirms this point. He points out the various complications that come with implementing problem/project-based learning such as "students spend more time on their studies with a PBL model… they may miss part of the

[1] Link

broader perspective or breadth of knowledge." He advises instructors implementing PBL into their lessons to ensure that students fill any potential 'subject area gaps' within the lesson. Keeping these studies in mind, PBL used in my experiment will address any subject gaps to ensure that students are not missing part of the knowledge. This way, I can accurately compare LBL and PBL as both will be implemented effectively in each group.

Furthermore, research on the differences between PBL and LBL on student performance in specific types of classrooms is plentiful. A prime example of this is found in the source: "Problem-based learning in comparison with lecture-based learning among medical students" by Rizwan Faisal, Sher Bahadur, et. al.[2] In this source, Rizwan Faisal analyzes the direct differences between the performance of medical students who were taught using PBL (problem-based learning) and LBL (lecture-based learning) through the use of an assessment. It shows the differences in problem-based learning and lecture-based learning and how problem based learning was more effective in helping students understand and remember the information being taught as shown by the better test scores. "The mean score for PBL and LBL sessions was3.2±0.7 and 2.7±0.8, respectively." (Faisal 2016) A visual chart is also provided by the research paper. (shown on the right) A clear distinction between PBL and LBL was shown when analyzing a medical institute. This research introduces the question: where else does the use of PBL help students flourish? In an attempt to answer this question several studies such as "Using integrated problem- and lecture-based learning teaching modes for imaging



[2] Link

diagnosis education” by Jun-Yan Yue, Jie Chen, Wen-Guang Dou, Chang-Hua Liang, Qing-Wu Wu, Yi-Yong Ma, Zhi-Ping Zhu, Mei-Xia Li, and Yan-Long Hu. explore the effectiveness of the implementation of PBL and LBL in classrooms. In this source, 60 students took part in the study in which they split the students into two groups, one learning from PBL and one from LBL. The students were then tested and a survey was conducted to evaluate the teaching method. The study showed “a statistically significant difference in the test scores" (Yue 2018) between the two groups. The group which was taught using PBL performed better, confirming the phenomenon performed in the previous findings of Faisal.

Both of these studies use a summative assessment in order to determine student understanding. According to Cornell.edu, student understanding and learning can be assessed through direct and indirect measures. An example of a direct measure being a summative assessment, and an indirect measure being student surveys. In my research, I will be using both of these methods to measure a student's understanding of the topic at hand: general relativity. Modeling my research on this previous research, I will assess the effectiveness of using PBL and LBL in high school physics classrooms focusing on the lesson of general relativity.

No specific research analyzes the difference between the students’ academic performance using specifically project/problem-based learning or lecture-based learning in high school physics classrooms focusing on the lesson of general relativity. I also plan to analyze the correlation between preference of instruction between PBL and LBL and the student’s achievement and performance on the assessment in high school physics classrooms focusing on the lesson of general relativity.. “Effects of Tiered Instruction on Academic Performance in a Secondary Science Course" by M. R. E. Richards & Stuart N. Omdal goes into tiered instruction and analyzes the effect on academic performance on it but doesn’t cover different types of

instruction used in the tiered model. A source closest to the proposed research would be “Problem-based learning in comparison with lecture-based learning among medical students" by Rizwan Faisal, Sher Bahadur, et. al, which directly compares the effect of lecture and problem based learning in medical student’s retention rates. Hence, my research will follow a similar path in attempting to compare and contrast the effectiveness of PBL and LBL when it comes to the lesson of general relativity in a high school physics classroom..

Rationalization for Method

In order to gain insight into my research inquiry I will be using a mixed method approach to the research. The reason I chose the experiment was because it would allow me to get data for student performance when related to the type of instruction they learned from. This would allow me to establish a correlation between instructional method and performance. I chose to include the survey in the beginning and end of the experiment in order to account for any confounding variables that weren’t accounted for in the experiment such as the motivation of the student and how much they believed that they learned. As in an experiment, I would be able to define the independent variable as the type of instruction and manipulate it to affect the dependent variable, which in this case would be the assessment scores, I would be able to prove causation for any correlations I find. This will allow me to effectively answer my research question and provide the data I need to explain the difference in effectiveness between PBL and LBL.

Previous Research

The main inspiration for this choice was based off of other research such as research published in the Journal of Pakistan Medical Association, named “Problem-based learning in comparison with lecture-based learning among medical students” by Rizwan Faisal. This source analyzes the direct differences between the performance of medical students who were taught

using PBL (problem-based learning) and LBL (lecture-based learning) through an assessment. It shows the differences in these instructional methods and how, in the case of medical studies, problem based learning was more effective in helping students understand and remember the information being taught as shown by the better test scores. I followed a similar method to assess the effectiveness of PBL and LBL in the lesson of general relativity in high school physics classrooms. This source however failed to take into account many confounding variables which I accounted for using a survey. I also used other sources as inspiration as using only one source may cause me to look over some things that the other source did. In order to reduce biases and skewed results, I took into account other studies such as "Effects of Tiered Instruction on Academic Performance in a Secondary Science Course" by M. R. E. Richards and Stuart N. Omdal.

Participants

For the participants of my study, I chose to assess a local high school in Middlesex County, New Jersey, in the United States of America. The students will be taking the AP Physics 1. These students will not be randomly selected by the researchers. Rather the classes chosen will be assigned to each group randomly. The privacy of the participants will be kept confidential as no personal information will be taken other than that of preference of instructional style. Each participant will be assigned a number so that there is no use of name as identifying information. The participants were chosen because they were a sample representative of other high school physics students learning general relativity in a high school in Middlesex County. All subjects chosen have some things in common such as: same teacher, same subject, and same school.

Significance

The goal of this project is to find the effects on academic achievement and retention rates of different styles of instruction, such as project based learning and lecture learning, and of student motivation in high school physics classrooms focusing on general relativity. As Einstein's theory of general relativity is a major portion of understanding some theories of how our universe works, I chose to study the effectiveness of teaching this lesson through different methods of instruction. As this concept may be difficult for some students to understand, it will allow me to gather information on which instructional method is best for teaching this lesson.

Procedures

For the procedures of my experiment I will:

- 2 groups will be assigned to 1 teacher; one where taught primarily using Project/Problem-Based Learning; one where taught using Lecture-Based Learning.
- 2 classes - all students in each class are picked randomly therefore bias is avoided and shows sample of a standard AP Physics 1 class in a public high school in Edison, NJ
- Experiment will first have a survey for all participants asking following questions:
    - What instruction method do you prefer?
    - How much of an impact do you believe motivation plays a role in the amount of information you grasp from a class?
- Each group will study a concept for 2 class periods.
- An assessment on topic given to each of the groups (Both a pre and post test)
    - First class period: Pre-test for around 15 minutes; teach about concept for rest of class
    - Second class period: teach about concepts for 30 minutes and post tests afterwards lasting 15 minutes.

- Given a post experiment survey asking following questions:
    - How would you rate your understanding of the topic?
        - Scale 1-5 (1 - don't understand at all; 5 - understand enough to teach the class)
    - How motivated were you to learn in this class?
        - Scale 1-5 (1 - not motivated at all; 5 - very motivated) [Your answers will not be shown to the teacher]

Any data I gather will be kept confidential and I will not collect any personal identifiable information. Using these procedures, if there is a correlation between instructional method and assessment, causation will be implied.

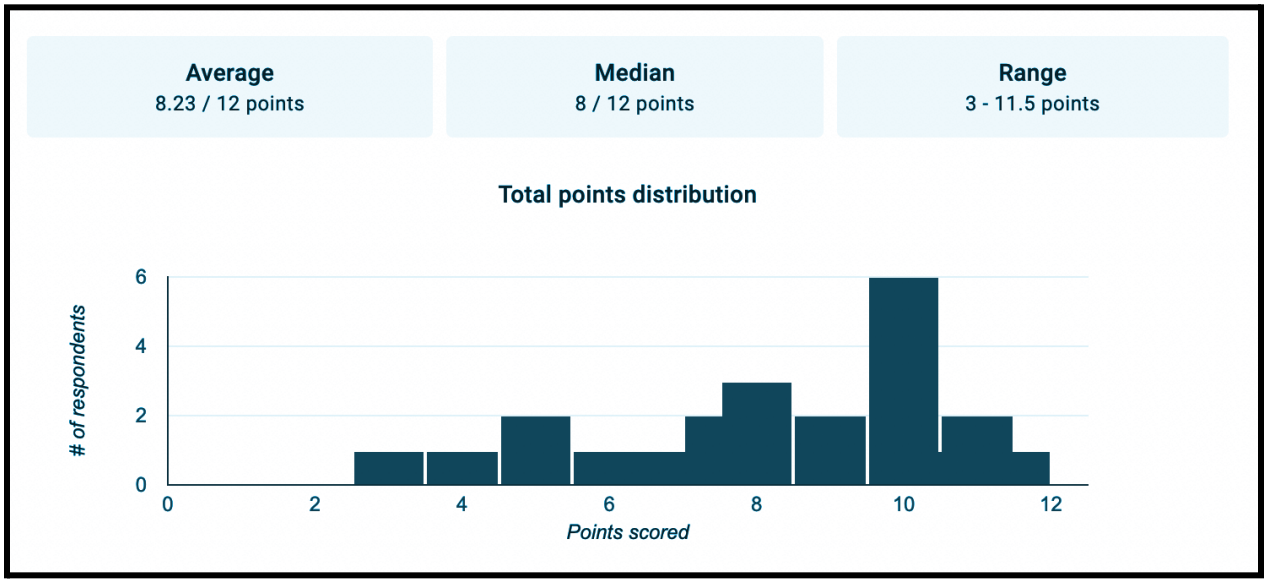
Analysis & Discussion

I chose to collect data using a survey + experiment method because I could get results from a controlled environment to compare the two instructional methods I was researching. The quantitative data that I collected from the experiment showed trends of the difference in the performance of each of the methods. I collected this type of data to find a way to compare the mean scores of those taught by PBL and those taught by LBL. I used statistical analysis in order to find various correlations from the data collected in my research. I found correlations for motivation and test scores, instructional method and test scores, and even preference and test scores. I had 51 participants across the two groups. I had 25 participants in Group 1 which was the class that learned from Problem/Project Based Learning. The other group, Group 2, had 26 participants who learned from Lecture-Based Learning.

Correlation: Instructional method and Assessment score

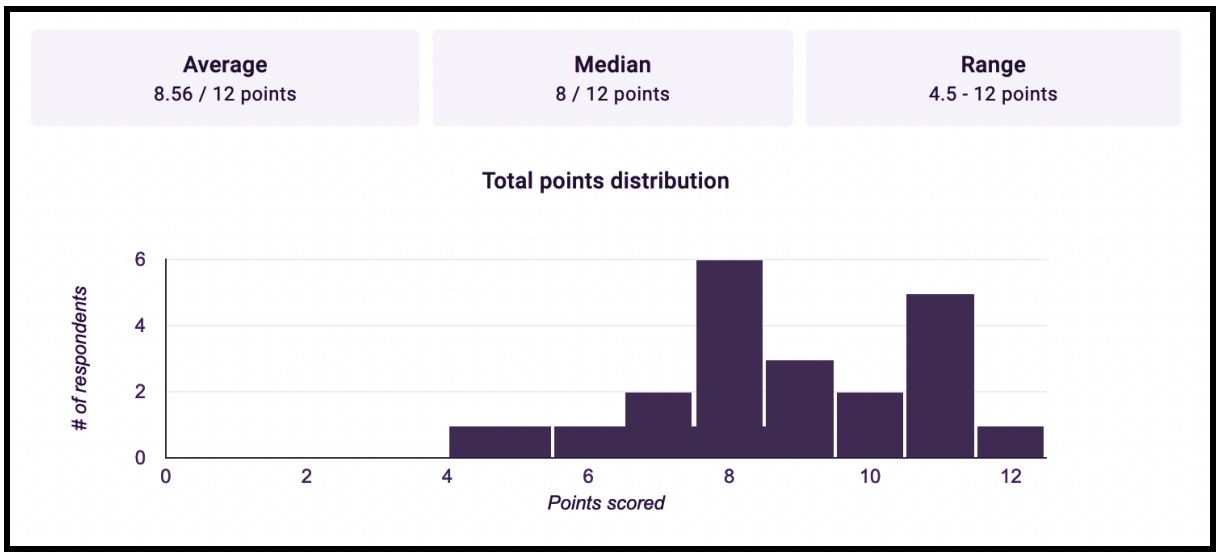
For the first correlation that I analyzed was the one that aimed to answer my research question and fill the gap. Finding a clear correlation between higher assessment scores and a certain instructional method would be a clear means to show that one instructional method was better than the other when teaching special relativity to high school students. The correlation between Lecture based learning and assessment scores can be displayed with the following chart:

Lecture Based Learning Group Assessment Scores



The data collected shows a unimodal data distribution which has a peak of 10 out of 12. The average of the scores for the LBL learning assessment was 8.23 and the Median was 8. The maximum score attained in the LBL class was 11.5. The standard deviation of the LBL Data was 2.36. Another chart can display the information collected from the Problem/Project Based Learning group:

Project/Problem Based Learning Group Assessment Scores



The data collected shows a bimodal data distribution which has the peaks of the scores of 8/12 and 11/12. The average of the scores for the PBL learning was 8.56 and the Median was 8. The PBL had a maximum score of 11. The standard deviation of the PBL assessment scores was 1.98. When directly comparing the two groups it is shown that the PBL group has a higher mean score than the other group with less variability among the data. In order to see if this was a statistically significant difference, I decided to conduct a 2 sample t-test which is a hypothesis that shows whether or not a null hypothesis is true or not, where H_0 is the null hypothesis and H_A is the alternative hypothesis.

Hypotheses:

H_0 : μPBL - μLBL = 0 (The difference between the true means of the samples is not significant.)

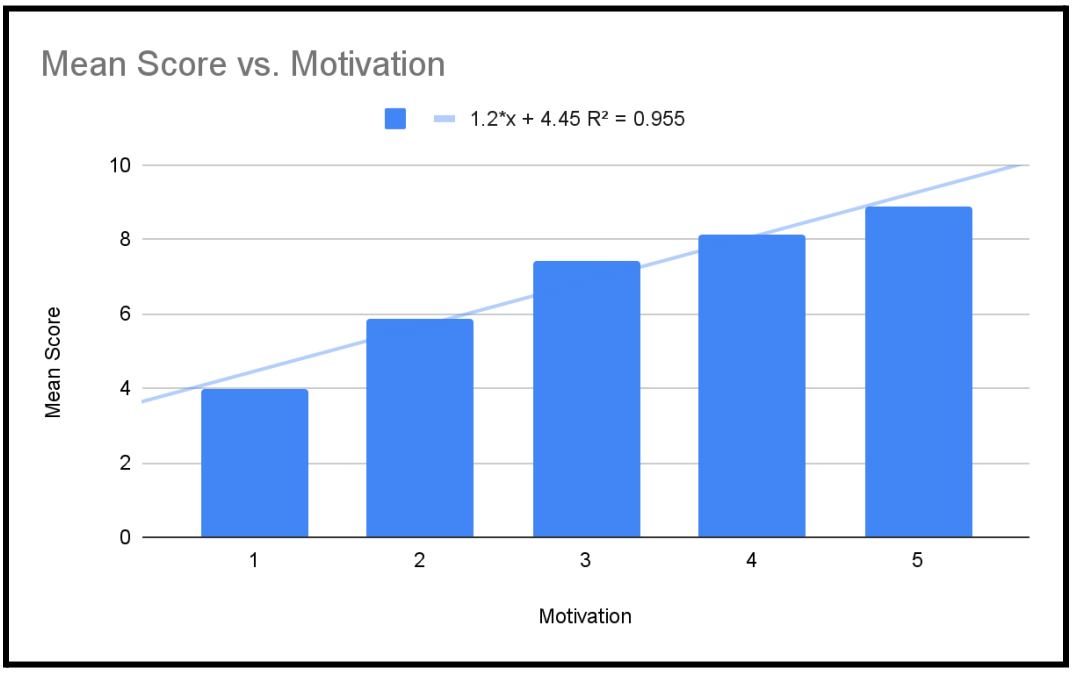
H_A : μPBL - μLBL > 0 (The difference between the true means of the samples is significant and the mean of PBL is greater than LBL.)

After conducting the test, I received a p value of .299 which under a 90% significance level, or confidence level, showed that there wasn't sufficient evidence to reject the null hypothesis

therefore there was no evidence that suggested that there was a statistically significant difference between the two groups when it came to assessment score. The data showed that the type of instructional method used didn't make a difference when it came to the assessment score. These results were surprising but I thought that this may be due to the other factors that I analyzed between the groups.

Correlation: Motivation vs Test Scores

The next correlation I decided to analyze to find the reason behind the lack of difference between the two groups was motivation. I wanted to know how much motivation played a role in how well a student performs in an assessment on the subject at hand. Due to my pre and post survey I was able to record the motivation of each student on a scale from 1 to 5. After analyzing the data the correlation was clear.

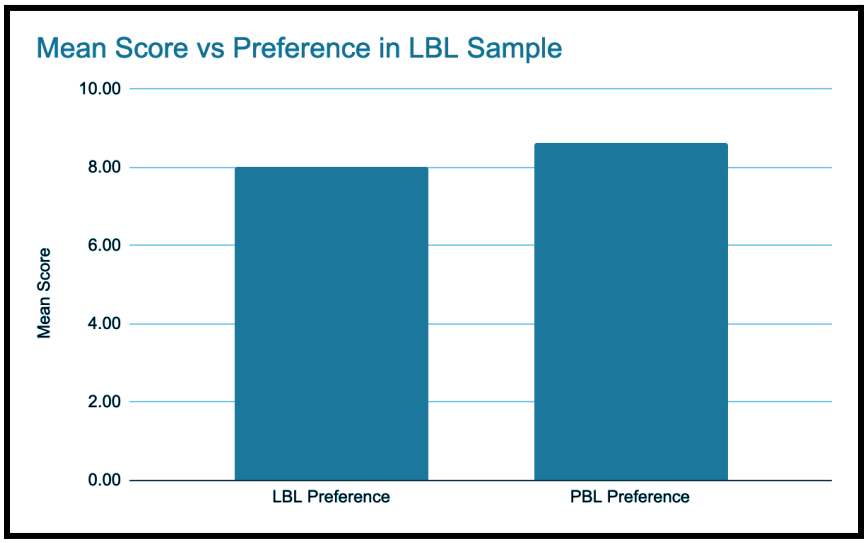


This time the data showed a correlation coefficient of 0.977241014 and an R2 value of .955 which showed that more than 95% of the data showed that there is a correlation between motivation and mean score, suggesting that the motivation of a student's willingness to learn

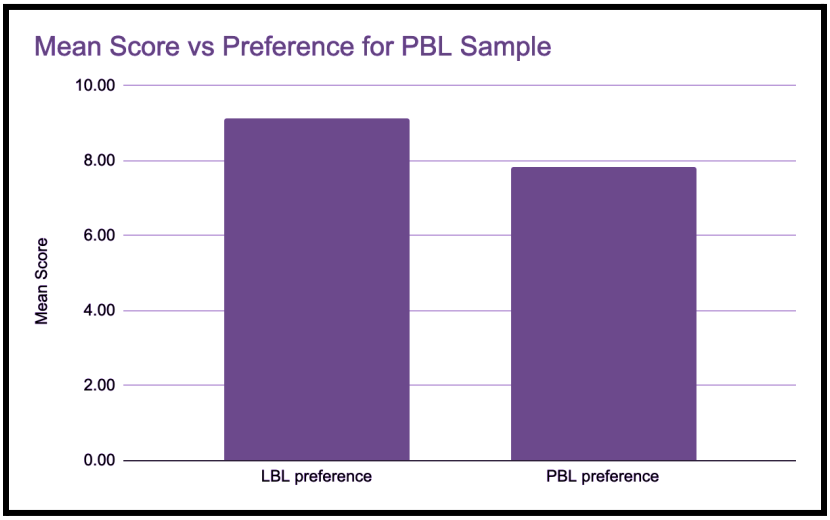
played a big role in both of the groups. These findings showed that beyond a doubt the students who were more motivated to learn in class performed better on the test. This may be because they spent more time paying attention to the lecture or spent more time completing the PBL activity. The Lecture-Based Learning group had a higher average motivation level with a mean motivation of 3.667 whereas the Problem-Based Learning group had a mean motivation of 3.44. However when I analyzed the trends for each individual group for motivation I found the same pattern where the higher the students motivation to learn, the higher their assessment score suggesting that the biggest factor when it came to learning was, rather than instructional method, the student's motivation to learn and pay attention in the class.

Correlation: Preference vs Assessment score.

I decided to account for another variable when conducting my experiment which was the preference of each student when it came to which instructional method they preferred and I found very interesting results. I found that when students were taught using the opposite instructional method that they preferred they had a higher mean score. Specifically, when I analyzed the lecture based learning group, I found that the mean score was higher for those who preferred Project/problem based learning. In the other group, where I taught using Project/Problem based learning I found the same correlation where those who had a preference for the opposite method performed better than those with preference



for the method taught. This may be caused because subjects feel that since they don't prefer the particular method of instruction they may pay more attention to it. It is more likely that this is caused because more subjects chose LBL than PBL in preference. Though, the true reason for this is unknown. Further research could be conducted to see if this pattern continues and if so what prompts such trends.



Findings/Discussion Continued

In all, my research provided evidence that there was no statistically significant difference when it came to assessment scores based on the type of instructional method used between Lecture-based learning and Problem/ Project Based learning for teaching special relativity to high school students. Though it was not what I was looking for, I found a strong correlation between motivation to learn and assessment scores. This suggests that instructors should focus on keeping their students motivated rather than focusing on the instructional method that they use. Certain instructional methods may be used to increase the motivation of students and those would most likely be the most effective in teaching high school students the theory of special relativity.

Conclusion

Therefore, though I didn't have sufficient evidence to support that there was any difference when it came to assessment score based on the instructional method used, the data collected showed that there is a clear correlation between motivation and assessment score. Due

to the nature of my experiment, a causational relationship between the variables is implied. This helps cover the specific gap in the research where there is no experiment showing the difference between the two instructional methods when it comes to Lecture Based Learning and Project/Problem Based Learning. It addressed this gap by showing there isn't much difference between employing the two in a high school classroom setting with an average of around 25 students.

Implications

This research shows instructors who teach special relativity to high school students that the type of instructional method they use aren't nearly as important as how much they engage and motivate their students. This research and data shows that the more motivated a student is the more likely they are to perform well on a summative assessment. Since the summative assessment is a means to assess how well a student understands the concepts of the topic at hand, in this case special relativity, a higher assessment score can also show a high level of understanding. The overall goal of an instructor or teacher is to help students learn. A student will learn much more efficiently and effectively when they are more motivated to do so. For example, a very motivated student in a lecture class would pay more attention to the actual lecture and may take detailed notes throughout the lecture whereas a student who isn't motivated much at all will likely not pay attention no matter how good the lecture is. The teacher's lecture may explain the topic extremely well and clearly but if the student is not willing to listen, or motivated to, they will not learn from it. This phenomenon is analogous when it comes to Problem/Project-Based Learning, where if a student has a lower motivation level, they are unlikely to do all the activities in the PBL lesson. For example, in my research I had 6 activities of simulations to show the various properties of the theory of special relativity. In order to

perform well on the assessment a student had to have gone through all of the simulations to understand and apply the different concepts that would appear in the assessment. A motivated student would go through and find the means of looking for more information and completing all the tasks in the PBL assignment which would allow them to have a greater understanding and grasp of the concepts allowing them to perform well on the assessment. On the other hand, an unmotivated student wouldn't learn much from a PBL based lesson as they wouldn't go through all the activities and would skip over many of the concepts. Therefore, instructors should focus on motivating students when it comes to teaching special relativity to high school students as it is shown to have a much greater impact on student understanding than the type of instructional method used. The superiority of one instructional method would be if it is able to motivate a group of students more than other methods but this is very subjective as each group of students will be unique in the way they are motivated to learn.

Limitations

There were many limitations that arose when I was conducting my research. For example, when I first designed my study there were a plethora of limitations of the data, such as the amount of confounding variables, which included motivation and preference. I used a survey to account for these limitations showing that my experiment could show causation. However there were some limitations I couldn't avoid. One limitation was the sample size of my study. If I had more time I would be able to conduct the experiment multiple times with more samples of students which would allow me to get a better understanding of which instructional method is better and why. This would've also allowed me to account for the variability in student performance based on the time of day as I would perhaps be able to conduct the experiments at the same time every day with different students each time for a larger sample size. Another

limitation that should be considered is that I am not a certified physics educator and therefore may have made some mistakes when teaching. Though I thoroughly researched how to teach using the two methods, there may have been things I overlooked or dismissed when teaching due to my lack of experience. However to account for this I did have a physics teacher in the room when I was teaching in case I said anything wrong or explained anything incorrectly. One final limitation that I am unable to confirm is the matter that students may have cheated or collaborated on the exam without my knowledge. This would skew the results as some of the students would have gotten the same answers which wouldn't be able to be explained by the variables accounted for.

Future Research

This research lays the groundwork for future research in the sense that my experiment should be completed more times with a larger sample size to see if there is truly no significant difference between assessment scores when taught with Lecture-based learning and Problem/project based learning regarding the topic of special relativity in a high school physics class. Future research could go into which instruction is best for motivating students to learn as motivation is a major factor when it comes to student understanding.

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