Factors Shaping Students' Attitude and Persistence After Participating in a Summer Physics Course – A Mixed Methods Study

Dr. Gibin Raju **Paul Feldkamp** **Dr. Whitney Gaskins**
University of Cincinnati

Abstract

Enrollment in high school physics across the United States of America is notably lower than in other scientific disciplines. Given that physics serves as a prerequisite for admission into many STEM (Science, Technology, Engineering and Mathematics) degree programs, the lack of completion of this course at the high school level can significantly hinder students' readiness for and interest in pursuing STEM majors. Alarmingly, data reveal that two out of five high schools in the US do not offer physics courses, posing a significant challenge in meeting the industry's growing demand for STEM graduates. In response to this gap, the Office of Inclusive Excellence and Community Engagement in the College of Engineering and Applied Science at University of Cincinnati has initiated a summer physics program for local high school students. This study utilizes a mixed methods research design as a research methodology to understand the factors shaping the students' persistence after participating in this course. In the quantitative phase of the study, the participants completed Force Concept Inventory (FCI) and Attitude and Persistence towards STEM (APT-STEM) Instruments, with results indicating enhanced understanding of force concepts and more positive attitudes towards STEM after completing this course. Contrarily, the findings also suggested a decline in persistence. The qualitative phase involved an open-ended survey aimed at identifying factors influencing student persistence. Students reported challenges in comprehending mathematical terminology within physics equations. The paper concludes with a discussion on further research recommendations to enhance the high school physics curriculum, addressing the identified educational gaps.

Introduction

With the projected demand for approximately 1 million additional university graduates in STEM fields (Xue & Larson, 2015; American Immigration Council, 2022), the significance of high school physics has been anticipated to increase. Even though there is an increasing trend in the enrollment in physics (White, 2016), physics has the least enrollment among the sciences in the high school. According to the 2011 report by the National Center for Education Statistics, only 36% of high school students in the United States earned at least one Carnegie credit in a physics course in comparison to 96% in biology and 70% for chemistry (Nord et al., 2011). Recent data suggest that this figure has slightly increased, with only 42% of high school students enrolling in physics (Chu & White, 2021).

Given the importance of physics, there remains a demand to further improve enrollment, particularly in low socioeconomic school districts. Students in these areas are less likely to have access to and/or enroll in a physics courses compared to their counterparts in higher-income districts (White, 2016). Even if a student shows interest, there may be a series of barriers that prevent them from taking physics. Potential barriers to offering physics courses in school may include a shortage of qualified teachers, the absence of prerequisite course such as algebra, geometry, and pre-calculus, and misconceptions about difficulties and challenges associated with learning physics (Hazari et al., 2010). These factors influence student learning by affecting their experiences and prior knowledge of the subject.

Understanding these barriers, the Office of Inclusive Excellence and Community Engagement (IECE) has developed a program to offer physics courses to high school students. It was expected that taking this course would open a pathway for students to consider and be eligible for any STEM-related college admission. While our goal was to help remove a barrier, we were also interested in gaining insights into student learning experiences and factors influencing the learning experiences in an informal setting.

In this study, we used FCI to assess if our students had any existing misconceptions about force concepts before participating in the class. We also evaluated if their interest in pursuing a degree in STEM elevated after completing this course. This paper mainly focuses on answering the following research questions a) How do students' knowledge of the force concepts change over time as assessed by the Force Concept Inventory (FCI)? and b) What is the impact of completing the summer physics course on students' attitudes and persistence in STEM fields?.

Background/Framework

Informal Learning for High School

STEM Education has been generally practiced in different forms: formal, informal, or non-formal. Formal education usually occurs in a structured setting with an explicit curriculum, clear objectives and assessment mechanics. In contrast, informal and non-formal education occurs when the student chooses to acquire knowledge or skills in a particular field in a structured or unstructured settings, such as courses, workshops, and seminars (Saleh et al., 2020). As a result, this makes the informal learning completely a voluntary based engagement and takes place with a complete personal control, offering flexibility and autonomy (Commission of the European Communities, 2001). Informal STEM learning provides contextual experiences and interacts with reminiscence for a longer time in student learning with hands-on and minds-on activities and may offer free learning from a rigid curriculum (McCreedy & Dierking, 2013). Notably, informal STEM learning happens easier and anywhere regardless of time constraints. Studies show that 85% of the learning happens outside a formal classroom (Ainsworth & Eaton, 2010; Cuinen et al., 2012), with research indicating that informal research enhances interest, engagement, positive experiences, extended and deepened STEM content learning while providing access to content and materials that might otherwise be unavailable to high school students (King, 2017; Roberts et al., 2018; Morris et al., 2019). Notably, most schools in the largest local school district cannot provide physics course, placing students at a disadvantage when applying to university STEM programs. To bridge this gap, the university's physics program acts as an informal STEM learning initiative designed to remove obstacles for high school students. Completing a physics course in high schools is strongly correlated with beginning and completion of a degree in a STEM field, and making it a critical prerequisite, especially for engineering programs.

Project-Based Learning

Project-based learning (PBL) was embedded into the physics curriculum to support for student engagement. Project-based learning is a pedagogical approach by utilizing engaging activities to show students the real-world aspects of the subject matter. Research indicates that project-based learning significantly bolsters students' problem-solving skills and self-efficacy (Samsudin et al., 2020). When students believe in their ability to succeed, particularly in their capacity to solve complex problems and handle challenging tasks in physics, they are more likely to achieve success. The objective was to empower students with knowledge and skills necessary to apply physics concepts in real-world situations. Students engaged in multiple hands-on activities crucial to their motivation. For example, when teaching momentum and forces the instructor had civil engineers visit the classroom to demonstrate a shake table, a device used to simulate the dynamic effects of motion on structures to test their resistance to seismic activity, thereby offering a practical demonstration of these physics concepts in actions (Kjolsing & Einde, 2015). The students then were given the opportunity to build their own miniature building from materials provided to them to test their building under the influence of a simulated earthquake. To make the content more understandable for students we incorporated real world problems that utilize concepts from physics in their solutions. It was also observed from a study that the introduction of engineering design process into science classes increased the interests of students in STEM careers (Moore et al., 2013).

Force Concept Inventory (FCI)

FCI has been widely used as a test instrument in physics education. This test instrument is a 30-item, five-choice survey to probe the understanding of Newtonian mechanics. Since the validity and reliability of the FCI are excellent, FCI has been used by many educational interventionists as an assessment tool to measure the effectiveness of classroom instruction. Students' misconception of kinematic and dynamic concepts has been the subject of research among researchers (Montfort et al., 2007; Mufit & Fauzan, 2019). Even though there were numerous studies on this area, only limited studies focused on high school students because understanding the concept in senior high school is not usually considered a priority. Using FCI in this study will help understand if students are learning the subject matter.

STEM Attitude and Persistence

Fostering inquiry skills and positive attitudes are considered important traits that a student should possess to be successful in a STEM career (Perdana et al., 2021). When students enter high school, many find science boring, difficult, and irrelevant to their day-to-day life (Paul et al., 2020). This causes a decrease in the number of students studying and entering STEM fields. Due to the low interest of students in understanding STEM, it is imperative to find strategies that will help motivate the students to pursue STEM. Because motivation generates the interests that help students take control of their learning, it will also provide them with greater independence through challenging opportunities. Since instructors play an important role in affecting the attitudes of their students, they are commonly looking at different strategies to engage students while developing critical thinking and content knowledge for their future success in the field Riegle-Crumb et al., 2015). Along with attitude, it is very important for the students to have persistence in continuing in STEM fields. Persistence is defined as passion for preserving through long-term goals that falls under the umbrella of perseverance (Duckworth & Quinn, 2009; Gutman & Schoon, 2013; Rojas et al., 2012. Both attitude and persistence are utmost necessary characteristics for the students to stay focused in STEM field. In this research, we have used the instrument that is developed by Sunny et. al (2018) to gauge the student's attitude and persistence towards STEM before and after participating in the class.

Demographics	
Gender	
Men	3
Women	10
Race	
Asian	2
Black or African American	10
White	1

Table 1. Demographics of participated students

Data and Methods

Course Setting

The physics course is a four-week class and counts for an advanced high school science credit. The purpose of this course is to provide an opportunity to strengthen student's admissions application for STEM programs at a university. Most colleges require incoming first year students to have taken a high school physics course to be admitted as an engineering or science major (Main & Griffith, 2022). Ensuring students have taken this course is important to be prepared for the transition between high school and college. There are several issues with this requirement. First, not all Cincinnati Public Schools offer physics within their curriculum (Hughes STEM High School, 2024). This places students with future engineering interests at a complete disadvantage. Secondly, oftentimes, schools that may offer physics courses do not offer the course in each student's "track" for graduation. This means that a student may go to a school that offers physics but is unable to take it before graduation (Hughes STEM High School, 2024). The physics course offered by IECE attempts to bridge the gap between high school students and engineering. In the 2022 class there were students from seven different schools in the greater Cincinnati area.

The course is held on the University of Cincinnati campus Monday through Friday 9:00 AM to 12:00 PM. Students were provided with complimentary bus passes to assist in their transportation to and from campus. They were also provided with the materials necessary for completing the course at no cost. Students were provided with a continental style breakfast each morning. Due to the volume of work included in the four-week course, students were informed that missing a day(s) would be comparable to missing a week(s) of class.

The course was comprised of five sections, Motion (1.25 weeks), Momentum and forces (1.25 weeks), Energy (.5 weeks), Electricity and Magnetism (.5 weeks), and Waves (.5 weeks). Each week of the course included at least 2-3 hands-on activities, one lab tour (field trip) and at least one day of group work. On two different occasions, local engineers spoke with the students and led activities with the students in the classroom. Examples of activities in the classroom included: Robotics, catapults, bottle rocket launcher, and advanced paper airplane kits. Grades were based on student's participation and demonstration of understanding of the topic. The students were given access to contact instructors before or after class for additional help. Groups were selected by the students for team projects.

Curriculum

As stated previously, the curriculum was divided into 5 sections: Motion, Momentum and Forces, Energy, Electricity and Magnetism, and Waves. Each of the five sections were designed to be interactive using PBL. This included lab tours, hands on activities and group projects. In the Motion portion of our curriculum, students worked on projects with water bottle rockets, robots and catapults. In momentum and forces, the students participated in tug of war, a shake table and visited bearcat motor sports to view a formula race car. The Energy section included exposure to roller coasters and a hot wheel track. During Electricity and Magnetism, students had the opportunity to work with an electrical engineer, visit a robotics lab where they worked with deconstructed robots, used a hand crank, and participated in a project with snap circuits. The Waves portion involved a lab tour with demonstrations of various microscopes. The lab tours were hosted on campus and by industry professionals. Students also had the chance to speak with current college students working in these labs to gain more peer-to-peer understanding of the field.

The entire course included exposure to hands-on physics experiences on these activities which were imbedded in the curriculum for the students.

Methodology

This study utilized a mixed method study as the research methodology. Researchers used an explanatory sequential approach to follow up the quantitative results with qualitative data. As a result, the collected qualitative data is used in the subsequent interpretation and clarification of the data from the quantitative data analysis. In this study design, QUAN design is the design emphasis, and a QUAL design is used in explanatory approaches. In the first phase of the study, researchers asked the students to complete a STEM Attitude Survey and Force Concept Inventory (FCI) before and after completing the course. FCI was also collected in the middle of the four-week course to evaluate progress. A comparison of these scores (pre and post) from this course was calculated. Based on these scores, researchers explored more on the student attitudes and experiences from the classes. Next, an open-ended survey was launched at the second stage of the study to better understand the scores students received from the instruments.

Positionality Statement

As Scharp and Thomas (2019) argue, research scholars in critical social science research should always assess how their own position and experiences might contribute to their interpretations of the others lived experiences. With this philosophy in mind, the authors have not taken or been part of summer high school program in a university. Before we put forward the findings and in the spirit of self-reflexivity, the first researcher recognizes his standpoint as an Asian man who is pursuing his doctorate in Engineering Education in the Department of Engineering and Computing Education with an aerospace engineering and education background. The first researcher is not an active participant in the Black community. He also attended high school in a foreign country where the education was delivered in a traditional pedagogy format, where information is provided by a textbook and presented by the teacher. He did not experience any PBL, or any type of informal STEM learning during his schooling. The second researcher is a white male educator and researcher with a degree in Community Support Services and is currently pursuing a Master's degree in Higher Education Administration. This researcher attended a high school with limited physics courses in his high school curriculum. This lack of availability directly influenced the researcher's success in physics in college and their passion for this project. The third researcher and creator of the Cincinnati Public School's Physics Strong course is an Associate Dean in a College of Engineering and an Associate Professor in the Department of Engineering and Computing Education. She is the first Black woman to receive a doctorate in Engineering at her institution (Biomedical Engineering). She oversees Diversity Equity and Inclusion in the College as well as Community Engagement. Her team works with the Office of Admissions to increase the number of Racial and Ethnically diverse students entering the college and generates programs, such as the with Cincinnati Public School's Physics Strong Program to expand pathways into the college.

Findings

The first phase of the study involved 13 high school students who completed Force Concept Inventory and APT-STEM instruments. The demographics of the students are elaborated in Table 1. Researchers graded the pre and post FCI instruments. After analyzing the data, it was observed that the student scores improved by 10.76% on average after taking the physics course. Figure 1 shows the pre and post scores of the FCI instrument. In the middle of the course, researchers collected one additional round of FCI data to gauge the impact the rest of course impact on student learning and it was found that student scores improved by 1.06 % on average. After exploring the FCI data, the pre and post scores of the APT-STEM instruments were analyzed. It was clear that the scores improved by an average of 17.14%. Researchers further explored the data to understand the change in attitude and persistence by separately analyzing them. It was inferred that the change in attitude was increased by 19% compared to their initial scores but change in persistence was decreased by 43.1%. The decrease in persistence is a clear indicator that students will not be persistent enough to continue in the STEM field.

In the second phase of the study, researchers emailed an open-ended survey to all 13 high school students to explore the reason(s) students reported a lower persistence after completing the course. Only 11 students responded to the survey (85% participation from the students who participated in the program). Table 2 tabulates the questions asked in the survey along with the codes generated and count of each code. The explanation of the codes will be explained in Table 3.

The first question on the survey focused on the student's decision to participate in the summer physics program. Most students responded to our survey indicating they needed the credit for this class. These responses were counted towards code "credit". Some of the responses from the survey are below.

> *"I wanted to have my physics credit before I started another school year so that I could focus on other core classes. Physics is also a required credit to my major when I get into college."*
>
> *"Because I was interested, and I wanted the credit as well"*
>
> *"Needed the credit"*
>
> *"I wanted to get credit for physics so that I would be prepared to graduate."*

Some of the students also mentioned that the course was recommended by someone and that is how they decided to pursue this course. These responses were counted towards the "recommended" code. Some of the survey re-

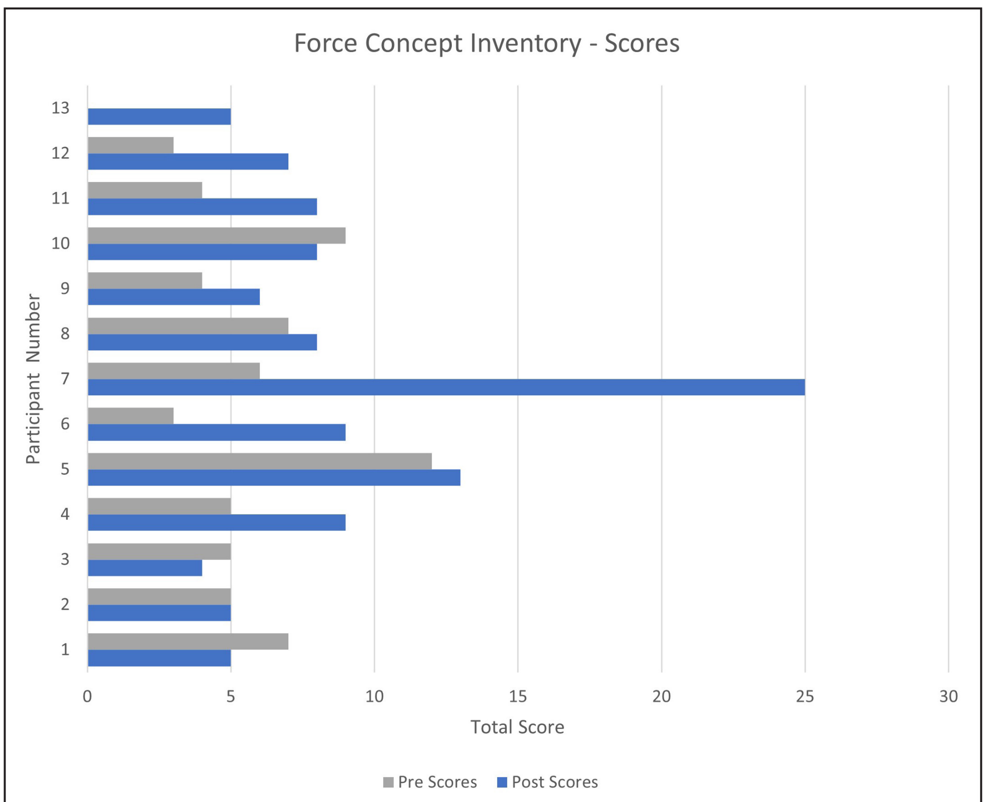

Figure 1. Force Concept Inventory - Pre vs. Post Scores

sponses are copied below.

"It was recommended to me by my chemistry teacher."

"It was recommended to me by my school librarian, and I want earn as many seals for graduation as possible."

"I love physics and science in general, my school counselor saw an email about it and though that I would enjoy it plus it would give me a head start on my school year with extra credits. I also did this because I intended to take collage level physics the following school term and thought this would be a good way to get a foundation in physics quick before I begun doing collage physics."

"I wanted to participate in the Summer Physics course because I was really struggling my junior year. I was failing my science course and my school counselor brought up this opportunity in a random conversation and I couldn't stop thinking about it. My school used to offer physics but then stopped, due to our physics teacher retiring. I always wanted to take it, so when I heard about the opportunity, I knew I had to take it."

One student also reported that they took the course because he was struggling and wanted to improve his grade by understanding the material. The second question focused on the student's favorite activity/class lecturer. All students reported that they loved the hands-on experiences which were counted towards the code "activities" and loved the site visits which were counted towards the code "lab visit". Some of the responses from the survey are copied below.

"Making the bill bottle rockets and visiting the motor sports lab."

"I honestly wouldn't be able to pick just one. I enjoyed all aspects of the class, from the group projects to the field trips across campus."

Next, students were asked to report what they found the most challenging during the course. All students reported that they found math difficult to understand and solve the concept problems. All such responses were counted towards the code "mathematics" and one student reported missing class was a challenge. Some of the responses reflecting these codes are mentioned below.

"The math was the most challenging part of this class."

"I found understanding the kinematic equations was the most challenging thing in the class."

"The hardest was the trigonometric functions."

Then, we asked students to report what changes they think should be made to the classes. Of the students who responded to that question, most said that there is nothing they would want to change. These responses were counted towards the code "none". One of the students recommended increasing the course length and another student mentioned describing the project more. Both the recommendations were considered towards the code "length" and "description" codes simultaneously. Some of the responses from this questionnaire are copied below.

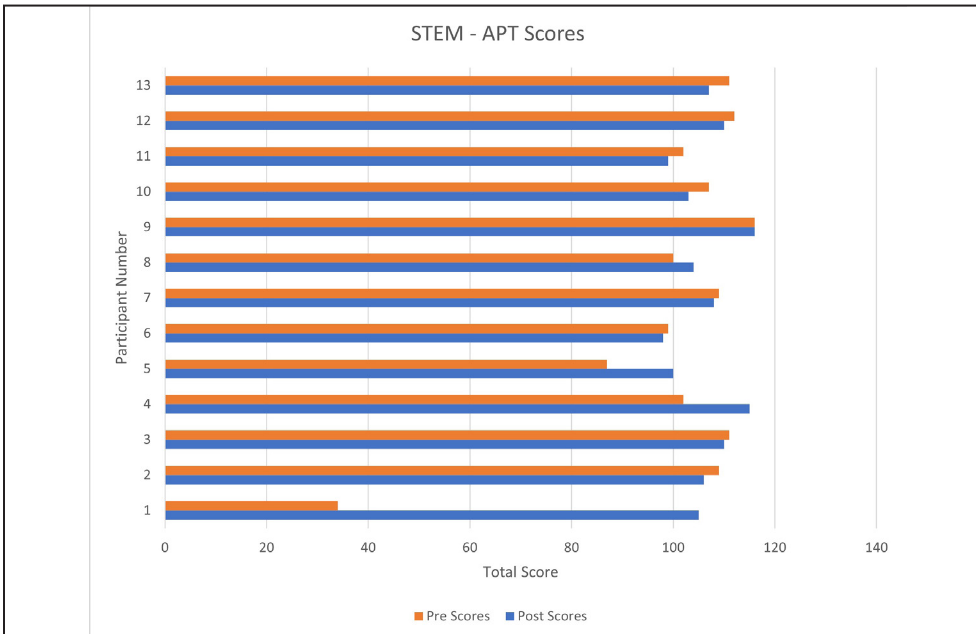

Figure 2. STEM- APT Instrument - Pre vs. Post Scores (Quantified)

Codes generated from the open-ended survey questions

Questions	Codes	Count
1. Why did you decide to participate in the Summer Physics course?	Recommended	4
	Credit	7
	Personal interest	7
2. What was your favorite activity/class lecture?	Activities	8
	Lab visit	4
3. What did you find most challenging during the course?	Mathematics	8
	Missing class	1
	Basics	1
4. What changes, if any, do you think should be made to the class?	None	4
	Length	2
	Description	1
	Checklist	1
5. Do you think the teacher created a welcoming learning environment? Please explain.	Welcoming environment	9
	Fun	3
	Excited	2
6. Would you recommend this course to a friend? Please explain.	Recommend	9
	Fun	5
	Less time	1
7. Did this course increase your interest to pursue a STEM degree? Please explain	Sort of	4
	STEM Career	5
	Increased	2

Table 2. Codes generated from the open-ended survey questions

"None, the class was great."

"I loved everything."

"I honestly can't think of something that could have been better; the teacher was very supportive and helpful, but in a way that we had to be assertive. He was very kind as well. He was very good at helping the class stay engaging."

Then we asked students for their opinions on teachers creating a welcoming learning environment. Everyone agreed that the environment was great, safe, and a welcoming environment for the students. All such responses were counted towards the code "welcoming environment". Students also reported that the teacher was fun and seemed excited while teaching the course.

"Absolutely. Coach X did an amazing job at creating a safe and welcoming environment. He was good at making us feel heard."

"I absolutely think that coach c created a great learning environment. He made us work together every day so that we were comfortable in knowing people in the class and he made it fun as well"

"Yes. Coach X was an amazing instructor who made sure that the class was very hands on with many fun projects and had us look at physics from multiple different viewpoints."

Then we asked if the students would recommend this course to their friends. All students who responded to this question mentioned recommending this course to their peers. Such responses were counted to the code "recommend". Students also mentioned that the course was fun and saved a lot of time.

"Absolutely, I believe that anyone who is interested in the field of physics should do this course, it was fast past dense but still extremely fun to do."

"I would recommend this course to a friend because it saves a lot of time, and I learned a lot in just one month."

"Yes. I think it was an amazing opportunity to meet new people, be on a college campus daily, and learn things in very cool and interesting ways."

Finally, we asked the students if the course increased their interest in pursuing a STEM degree. We received varied responses for this question. Responses varied from "kind off increased" to "possibly". All such responses were counted towards the code "sort of". Most of the students mentioned going into a STEM career. Those responses were counted towards the code "STEM Career".

"Sort of, I was already extremely interested in STEM and pursuing a STEM field, I intended into going into astrophysics and quantum mechanics."

"I still feel strongly about pursuing arts, but I am more interested in the engineering field."

"Possibly. I think it's cool to imagine myself working a career with STEM and it really excites me. I honestly might try to become a teacher of some sort of STEM-related subject, later in life."

Codes	Explanation
Recommended	Course was recommended by a teacher, librarian, or counselor
Credit	Took the course for credit
Personal Interest	Took the course because of personal interest
Activities	Students liked the activities the most
Lab Visit	Students liked the lab visits the most
Mathematics	Students reported that math was difficult
Missing class	Students felt catching up missed class was difficult
None	Student did not think any change should be made
Length	Student felt the course should be offered for a longer time
Description	The description needs to be clear
Checklist	Student felt checklist of work would have been helpful
Welcoming environment	Students found teacher to be more welcoming
Fun	Students found teacher to be fun
Excited	Students found teacher to be excited while teaching
Recommend	Students felt comfortable recommending this course to their friends
Fun	Students felt the course was fun
Less time	Students felt the course only consumed less time
Sort of	Students felt the course sort of increased their interest to pursue a STEM degree
STEM Career	Students mentioned about pursuing STEM Career

Table 3. Codes and its explanations

Discussion

In this study, researchers utilized a mixed methods research design to investigate the factors shaping the students' persistence following their participation in a summer physics program. The quantitative phase aimed to assess changes in students' understanding of physics concepts using FCI within a project-based learning context in an informal setting. The findings from this phase indicated a significant improvement in students' conceptual knowledge as measured by the FCI. The FCI served not only to identify students' misconceptions but also to inform instructors about areas within the six conceptual dimensions of the FCI where the students commonly struggled, thereby guiding targeted instructional improvements to enhance learning outcomes. This standardized measure facilitates the evaluation of various teaching strategies, technologies, and learning environments on students' conceptual understanding of fundamental concepts in physics (Gedamu et al., 2022). However, it is critical to align these findings with broader academic discourse. The positive outcomes observed in our study, as indicated by pre- and post FCI assessments, seem to diverge from the consensus in the literature (Coletta & Philips, 2005). This discrepancy invites a critical examination of the conditions and pedagogical approaches in our program that might have contributed to the atypical success observed, suggesting that the factors unique to our project-based learning environment in an informal setting could have had a significant impact.

However, the quantitative analysis also revealed a paradox: while students' attitude towards STEM improved, their persistence in STEM declined. From the open-ended survey responses, it became evident that difficulties with kinematics equations signaled a broader challenge with kinematics concepts. This discovery prompted further investigation into the reasons behind the decrease in persistence. The survey responses clarified that the physics course itself was not the deterrent; rather, students expressed appreciation for the interactive class environment, including activities, group projects, and lab visits. They felt well-supported by the instructor and identified no areas needing improvement within the course structure. Despite this, the struggle with mathematics emerged as a significant hurdle, hindering comprehension of essential physics curriculum components and contributing to decreased STEM persistence.

Several researchers have discussed mathematics proficiency being one of the pressing issues on the student's persistence in the STEM (Sithole et. al, 2017). According to Hewson (2011), "students who freeze at the sight of numbers or equations will most certainly underperform" in STEM. Popham (2005) and Geary (2013) have also discussed how difficulties with mathematical concepts can foster negative attitudes towards mathematics, impacting students' overall success in STEM fields. Geary (2013) also reported that students' challenges in learning mathematics can be due to slowness in development of cognitive mathematical representations which was reflected in a student's response to the survey as "Something that was really challenging for me was the concept of moving things and trying to calculate when those things would get to a certain spot." The highlighted challenge regarding the concept of moving objects and calculating their arrival time does not reflect mathematical difficulties but also underscores the critical role of literacy in STEM education. The strong correlation between reading and mathematics skills suggests that literacy issues may compound the challenges students face in understanding and applying mathematical concepts (Shanahan & Shanahan, 2008).

Moreover, the difficulties in reading comprehension, particularly in interpreting scientific texts, highlight a broader issue that extends beyond mathematics and encompasses the entirety of STEM education (Fang, 2004). The recommendation to teach students how to read science effectively is pivotal. By developing strategies to navigate the specialized language of science, including its complex sentence structures and technical vocabulary, students can better engage with and understand scientific concepts and principles.

Conclusion

The summer physics program aimed to grant high school students, particularly those from underrepresented groups, access to physics curriculum through authentic, hands-on learning activities, thereby fostering an interest in STEM careers. The study demonstrated that project-based learning in an informal setting enhanced the participants' understanding of physics concepts when examined using the Force Concept Inventory. Additionally, there was a noticeable improvement in students' attitude towards STEM when they engaged in such environments. While the program specifically centered on increasing the attitude and persistence in pursuing a STEM career, it also provided valuable insights into further barriers that need addressing to achieve this goal more effectively.

The research study highlighted the positive impact of an informal learning environment on students' attitude towards STEM Education. The incorporation of project-based learning enabled students to connect physics with real-world applications, such as rocket design and kinematics in engineering, through various hands-on activities and laboratory visits. This summer program fostered a learning environment that not only enhanced STEM content knowledge but also provided opportunities and access to resources typically unavailable to these students. The value of authentic hands-on activities and interactions with STEM professionals was recognized as crucial to the learning process.

However, the current landscape of educational budget cut poses significant challenges, including a shortage of qualified physics teachers and limited access to such comprehensive curriculum content in schools. This situation unfortunately leads to "receivement gap", disproportionately affecting Black and Latinx students, leading to inequitable access to engaging and authentic experiences that bring content to life (Chambers, 2009). The findings of this research affirm that the program was successful in its implementation and in providing the opportunity for students to pursue a career in STEM. Feedback about the course, instructor, activities, lab visits were all positive and encouraging with fewer recommendations to improve the program or structure of the curriculum. Nevertheless, the preexisting barriers, such as limited prior knowledge, difficulties with mathematics integral to the course, were identified as significant obstacles potentially affecting students' persistence in STEM. Further research is warranted to investigate these factors and develop strategies to mitigate their impact on students' pursuit of STEM careers.

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Dr. Gibin Raju is a Research Assistant working at the Department of Engineering and Computing Education in the University of Cincinnati College of Engineering and Applied Science. Gibin earned his Bachelor of Technology in Aerospace Engineering, his Master of Science in Aerospace Engineering, his Master of Arts in Educational Studies, and his Doctor of Philosophy in Engineering Education. His research interests are focused on spatial skills, engineering design, cognitive stress, cognitive load, STEM accessibility issues, workforce development, engineering pathways, STEM education, ID/ODD, and education practices.

Paul Feldkamp is the Program Coordinator for the Office of Inclusive Excellence and Community Engagement in the College of Engineering and Applied Science. Paul's work focuses on diversity, equity and inclusion, pulling from his experiences with underrepresented populations. He has worked on multiple research projects focusing on underserved and underrepresented populations in engineering/STEM. Paul is a native of Cincinnati and earned his bachelor's degree at Morehead State University. He is currently pursuing his masters in Higher Education Administration and will begin pursuing his doctorate in 2025. Prior to working in higher education, he worked in the k-12 education system.

Dr. Whitney Gaskins is the Associate Dean of Inclusive Excellence, Community Engagement and Faculty Development in the University of Cincinnati College of Engineering and Applied Science. Whitney earned her Bachelor of Science in Biomedical Engineering, her Master of Business Administration in Quantitative Analysis and her Doctor of Philosophy in Biomedical Engineering/Engineering Education. In 2009, she founded The Gaskins Foundation, a non-profit organization, who launched the STEMulates year-round K-12 program, which is a free of charge program that introduces more students to math and science, that currently offers programming in five cities.