Himalayan Physics

Student outcomes in secondary physics flipped classrooms: An explanatory sequential mixed methods investigation

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Abstract: This study investigates whether the flipped classroom approach enhances secondary-level students' learning achievement in a Secondary-level Physics course. It aimed to explore the effectiveness of the flipped model for students who have been primarily exposed to traditional lecture-based instruction throughout their schooling. An explanatory sequential mixed methods design was employed. Quantitative data were analyzed using ANCOVA to compare pre- and post-test results between experimental and control groups of urban and rural schools in Gandaki Province of Nepal. The quantitative analysis was followed by qualitative interviews to interpret the quantitative findings. The results indicated that the flipped classroom did not significantly improve student performance in the urban school, but showed a near-significant trend toward improvement in student performance in the rural school. Notably, in the urban school, students in the control group, who received traditional instruction, outperformed those in the flipped group. These findings suggest that the success of the flipped classroom approach is highly context and lived-experience-dependent and influenced by factors such as students' readiness and access to digital resources.

Keywords: Nepal • Physics • Flipped classroom • Secondary level • Academic achievement • Resistance to change

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I. Introduction

The flipped classroom represents a pedagogical shift that promotes student-centered learning, where learners take responsibility for constructing their own knowledge. It is a teaching method where students are provided with lecture content in the form of video or other ICT-related resources before the class session, allowing class time to be utilized for activities that promote a deeper understanding of the concepts [1]. The flipped classroom instructional model is said to be effective in promoting self-directed

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learning and preparing students to participate actively during class, which consequently improves their learning achievements.

O'Flaherty and Phillips [2] have argued that the flipped classroom fosters a student-centered learning environment, supporting learner autonomy in constructing knowledge. Studies such as those by Avery et al. [3] and Sun et al. [4] have shown that the flipped classroom enables students to learn at their own pace, improves learning attitudes, and increases their commitment to studying. Similarly, White et al. [5] reported that the flipped classroom is an effective pedagogical approach that allows students to become independent learners. In a study of flipped physics classrooms, Yilmaz and Baydas [6] found that the approach helped students show greater engagement due to interactive in-class activities that focused on applying and discussing the theoretical content learned in advance.

Likewise, Weaver and Sturtevant [7] reported cognitive benefits associated with this approach. Their study found that students in flipped classrooms, where traditional lectures were replaced with online videos and class time was used for collaborative problem-solving, performed nearly one standard deviation higher on standardized general chemistry exams compared to students in lecture-based classrooms. A recent study by Bitzenbauer and Hennig [8] on university-level students reported a positive influence of the flipped classroom model on students' learning behavior and their self-reported academic performance.

While many researchers have reported positive results of the flipped classroom, there are studies which have reported inconclusive conclusions about the effectiveness of the flipped classrooms. One such study was done by Colbert-Getz [9] which examined the effectiveness of a flipped classroom model in an anatomy course at the University of Florida. The results showed no significant difference in students' academic achievements. Although the results of implementing the flipped classroom approach are not persistently positive in all contexts and populations, it has been a widely adopted pedagogical approach in many parts of the world.

Similar to other parts of the world, the flipped classroom approach is gaining attention and adoption in Nepal, both at school and higher education levels. However, there is still a lack of research on its effectiveness at the secondary level, especially in physics education. Specifically, the effect of the flipped classroom on students' learning gains in physics at the secondary level has not been studied in the context of Nepal. It is not yet known whether the flipped classroom can improve Nepalese students' achievement in physics, given the cultural differences in teaching, learning, and knowing. This study attempts to examine the effectiveness of the flipped classroom approach in a public and a private secondary school in Gandaki Province, Nepal.

The purpose of this study is to examine the effectiveness of the flipped classroom approach in a secondary-level physics class. An explanatory sequential mixed-methods design has been employed, which involves collecting quantitative data first and then explaining the quantitative results with in-depth qualitative data. In the first, quantitative phase of the study, pre- and post-learning achievement data were collected from participants in their respective schools. The second, qualitative phase was conducted as a follow-up to the quantitative results to help explain the insignificant or borderline aspects of the findings. This study will answer the following research questions:

1. To what extent does the flipped classroom approach affect the study gains of secondary-level physics students compared to a traditional instructional approach in a quasi-experimental setting?
2. How do the students describe their learning experiences in the flipped classroom, and how do these perceptions help explain the observed study gains?

The flipped classroom approach is grounded in constructivist learning theory. Constructivism views learning as an active, student-centered process where learners build new knowledge upon their existing understanding. By engaging with instructional content before class and participating in interactive, collaborative tasks during class, students take an active role in their learning. This process supports the development of deeper conceptual understanding, as students construct meaning through problem-solving, discussion, and reflection. The theory also emphasizes Vygotsky's social constructivism, which aligns with the peer collaboration and teacher facilitation integral to flipped classroom sessions. This theoretical perspective provides a basis for understanding how the flipped classroom model may influence students' learning outcomes and experiences.

This study is significant in the context of Nepal. Science teaching in Nepal, including physics, is mainly based on traditional lecture methods. These approaches often limit student engagement and deeper conceptual understanding. The flipped classroom offers an alternative, student-centered approach in which students engage with learning materials outside class and take part in active, collaborative activities during class time. By exploring both the academic gains and students' experiences, this study contributes to the growing need for innovative teaching approaches in Nepalese schools. It also fills a gap in educational research in Nepal, particularly in the area of technology-enhanced instructional strategies in science education.

Basics of the flipped classroom

The flipped classroom, first described as an "inverted classroom" by Lage et al. [10], is an instructional approach in which students engage with course content at home through technology-based resources or readings. The classroom activities are designed to help students apply and master the home-read content through interactive activities, guided problem-solving, and discussions [11]. White et al. [5] define this approach as requiring students to engage in self-directed learning. This approach, White et al. posit, prepares students for active class participation. According to White et al., the flipped classroom is a pedagogical shift from traditional teaching and learning methods that promotes student-centered learning. The flipped classroom allows learners to take responsibility for constructing their own knowledge.

Other researchers [3, 4, 12] have suggested that the flipped classroom model allows students to learn at their own pace, develop positive learning attitudes, and enhance their commitment to studying. Studies have also reported cognitive improvements associated with this approach. For instance, Weaver and Sturtevant [7] examined the effectiveness of a flipped classroom model in a general chemistry course. By replacing traditional lectures with online videos and using class time for collaborative problem-solving, they found that students in the flipped classroom scored nearly one standard deviation higher on standardized general chemistry exams. Similarly, Morring et al. [13] observed a statistically significant increase in the number of students achieving A and B grades, along with reduced failure and withdrawal rates, in a large-enrollment organic chemistry course at Georgia State University in the US.

Despite these positive findings, some researchers have reported minimal or no significant differences in student performance due to the flipped instructional approach. Morton and Colbert-Getz [9] examined the effectiveness of a flipped classroom model in an anatomy course at the University of Florida. The results showed no significant difference in performance on lower-order cognitive tasks, such as recall and comprehension.

Constructivism and flipped physics instruction

The flipped classroom aligns with constructivist learning theories that emphasize active engagement and student-centered learning. Lo et al. [14], in their synthesis of mathematics and science flipped classrooms, proposed design principles such as using structured pre-class activities and allocating in-class time for guided problem-solving. These strategies, when implemented in physics education, as the authors indicated, are able to foster deeper conceptual learning and critical thinking. Similarly, Yilmaz and Baydas [6] conducted a meta-analysis revealing that the flipped model in STEM fields, including physics, generally leads to improved academic performance and increased motivation. Their findings suggest that students in flipped physics classes often demonstrate enhanced engagement due to interactive in-class activities that focus on applying and discussing theoretical content learned beforehand.

Akçayır and Akçayır [15] reported that flipped physics classes promote higher student engagement and allow more individualized feedback during classroom activities. However, they cautioned that the success of this approach hinges on students' ability to access and comprehend the pre-class materials independently. The authors mentioned that such skills are not uniformly present among all learners, particularly in settings with limited digital literacy.

Student engagement and self-regulation in physics

Despite its theoretical benefits, the flipped model demands a high level of self-regulation, especially in physics, where students must engage with abstract concepts often presented in complex language or visual representations. Researchers such as Ngo and Yunus [16] have emphasized that self-regulated learning plays a critical role in flipped environments. In the case of physics, students must not only manage their time effectively but also understand how to navigate and learn from digital videos or simulations. When these cognitive and metacognitive demands are not met with sufficient support, students may struggle to prepare adequately, leading to poor in-class performance and diminished learning gains. Talan and Gulsecen [17] found that while flipped physics classrooms improve classroom participation, the format may disadvantage students who are used to teacher-led instruction and who find it difficult to shift toward self-directed learning. This issue is particularly pronounced in physics, where the pre-class content, if not carefully scaffolded, is likely to overwhelm students who lack foundational knowledge or confidence.

Access and cultural readiness

In low-resource contexts such as Nepal, the challenges of implementing flipped physics instruction are magnified. While digital pedagogy has expanded during the COVID-19 pandemic, the divide in access and infrastructure remains substantial. Bond et al. [18] and König et al. [19] observed that during the COVID-19 emergency, remote teaching, student engagement in STEM subjects declined sharply in environments where digital readiness and support structures were weak. The researchers noted that both faculty and students in many Global South contexts struggled to adapt to online modalities, especially in technically demanding subjects like physics.

Pun [20] and Poudel [21]) have reported that the digital readiness among students varied widely between rural public schools and urban private institutions. Students from rural public schools, despite facing significant access limitations, were more receptive to pedagogical innovations like flipped learning. Conversely, students from high-performing private schools were more resistant to change and expressed discomfort with independently engaging with unfamiliar physics content before class. The authors have highlighted how cultural conditioning around instruction can impact the effectiveness of the flipped model.

Flipped classroom and students' performance in physics

Several studies have specifically explored the impact of the flipped classroom on physics education. Akintolure et al. [22] conducted a quasi-experimental study on secondary school students' academic performance in practical physics. One hundred senior secondary students were purposively selected and assigned to experimental and control groups, with the flipped classroom model applied to the experimental group and conventional teaching used for the control group. While pre-test results showed no significant difference between the groups, post-test scores revealed a marked improvement among students in the flipped classroom. These findings suggest that the flipped model positively influences academic performance in practical physics and has broader implications for teaching and learning.

Similarly, Tunggyshbay et al. [23] reviewed thirty studies on flipped classroom applications in physics instruction. Their analysis highlighted that flipped learning enhances student motivation, engagement, and problem-solving skills compared to traditional teaching methods. A meta-analysis by Manlapig Jr. [24] further confirmed that the flipped classroom model is an effective tool for improving student achievement across various physical science disciplines at the junior high, senior high, and college levels.

While research on the effectiveness of the flipped classroom in other subjects, such as chemistry and social sciences, remains inconclusive, studies indicate that it is beneficial in secondary physics education. The flipped classroom approach fosters student engagement, promotes active learning, and leads to improved academic performance. However, its success depends on careful planning, high-quality instructional materials, and teacher preparedness to facilitate in-class discussions and activities effectively [24].

Success in flipped physics classrooms

Researchers have contended that teachers must address both pedagogical design and student readiness if flipped learning in physics is to be successful. High-quality pre-class materials that complement in-class activities and scaffold difficult concepts are essential for successful flipped physics classrooms [14]. Particularly for learners from diverse backgrounds, these resources must be available in terms of language, format, and duration.

Reports have highlighted the importance of teachers needing professional development activities to apply flipped instruction in physics effectively. According to Valtonen et al. [25], rethinking instructional strategies is necessary to transition from digital competence to digital pedagogy. In physics education, where practical experience, supervised practice, and conceptual discussions are essential, this shift is particularly crucial.

II. Method

Research design

This study employed the explanatory sequential design. The explanatory sequential design begins with the collection and analysis of quantitative data, which is followed by the collection and analysis of qualitative data [26]. The study employed this method to provide an explanation or expansion of ANCOVA results.

In the first phase of quantitative data collection, the research employed a quasi-experimental design with a pre-test and post-test structure. The population included students from public and private schools in Nepal. Using purposive sampling, 26 students from a private school were selected as the experimental group, and 39 students were assigned to the control group. The experimental group participated in flipped classroom sessions. Similarly, another group of 40 students from a public school was purposively chosen. Of these, 21 students formed the experimental group, and 19 students were assigned to the control group.

In the second phase of the research, five students from the experimental groups from both schools were interviewed by the teachers who implemented the flipped teaching model. The intent of employing the explanatory sequential design was "to use a qualitative strand to explain initial quantitative results" [26].

Context and participants

Data were collected from two schools in Gandaki Province, Nepal. School 'A' was a private school in Pokhara, and School 'B' was a public school in Lamjung. School A is attended by children from well-to-do families who have easy access to digital resources at home and school. In contrast, students from School 'B' come from lower-income backgrounds. To ensure equitable access, the experimental group in School 'B' was provided with ICT facilities at school in case some students lacked access to digital resources at home.

Grade 11 students from School 'A' participated in the study. The experimental group comprised 26 students, while the control group included 39 students. In School 'B', Grade 10 students were involved in the study. Out of a total of 40 students, 21 had opted for Optional Mathematics, while 19 had chosen Economics. For this study, the group that chose Optional Mathematics was assigned as the experimental group, and the Economics group served as the control group.

Intervention plan and data collection

The flipped classroom interventions were implemented by experienced Physics teachers who are the second and third authors of this study. The participating classroom teachers themselves did not receive dedicated, structured training for implementing the flipped model. They relied on their general teaching experience. However, the research team (authors) prepared thoroughly beforehand. They first worked to understand the nuances of flipped classroom design. Key decisions, like choosing the experimental and control groups, were made during team meetings (for example, in the fourth meeting). Because of consent issues, the teachers implementing the flipped classroom ended up working with students at different grade levels. Grade 10 in School B and Grade 11 in School A. Since the intervention involved different grade levels, the coherence of the topics could not be maintained.

The two teachers separately taught Physics to both groups at different times of the day in separate classrooms at their respective schools. The second author designed a four-week lesson plan, including YouTube and Khan Academy resources, focusing on electrostatics, which was to be covered over three weeks. The third author designed a similar four-week flipped classroom plan for the Grade 10 students. The month-long plan for both groups is presented in Tables 1 and 2.

Before introducing the flipped classroom approach to one group and continuing with traditional methods in the other, a pre-test was administered on the intended content. This content had already been covered in the previous year's science curriculum. Care was taken to ensure the test assessed previously taught material from Grades 9 and 10. Fifteen multiple-choice questions with distractors were prepared and administered.

Qualitative data collection

The flipped classroom intervention totaled 22 and 30 hours for the experimental groups at urban and rural schools, respectively (See Tables 1 and 2 for the details). The control group received instruction on the same content for the same duration using traditional teaching methods. A pre-test was conducted before the intervention, and a post-test was administered one week after the three-week flipped classroom intervention. The pre-test followed the standard Secondary Education Examination model, including multiple-choice, very short, short, and long questions.

Table 1. Instructional plan of the teacher of School A

SN	Lesson	Working hours	Flipped Group Teach Materials	Control Group Teach Materials
1	Electric field and flux	4	Video, simulations	Teacher note, Book
2	Gauss-Law and it's applications	4	Video, simulations	Teacher note, Book
3	Electric Potential and potential difference	6	Video, simulations	Teacher note, Book
4	Capacitors and capacitance	4	Video, simulations	Teacher note, Book
5	Grouping of capacitors and energy stored in capacitors	4	Video, simulations	Teacher note, Book

Table 2. Instructional plan of the teacher of School B

SN	Lesson	Working Hours	Flipped Group Teach Materials	Control Group Teach Materials
1	Force and Motion	4T+2P = 6hrs	Video, PDF Text book, App	Teacher note Book, QB, Lab
2	Pressure	3T+1P = 4hrs	Video, PDF file QB, Practice Book	Teacher note Book, QB, Lab
3	Heat Energy	4T+1P = 5hrs	Video, AI tools QB, Book	Teacher note Book, QB, Lab
4	Lens	5T+2P = 7hrs	Video, QB App, Book	Teacher note Book, QB, Lab
5	Electricity and Magnetism	6T+2P = 8 hrs	Virtual Lab PDF, QB, AI tool	Teacher note Book, QB, Lab
Total	5 Lessons	30 Hours		

Qualitative data collection

The qualitative data collection was conducted after the quantitative data analysis had been completed. A semi-structured interview questionnaire was developed by the authors of this study and reviewed by all three authors to ensure its relevance, clarity, and alignment with the study's objectives. The administration of the interviews was carried out by the second and third authors, who were also responsible for implementing the flipped classroom approach with their respective students. All interviews were conducted in the private chambers of the participating students to create a familiar and comfortable environment for candid reflections.

Data analysis

In the first phase, to compare the effect of the intervention of the flipped classroom approach on the experimental group, ANCOVA analysis of covariance was used. The results of the covariance analysis were performed after controlling for the effect of the pre-test.

During the second stage, the qualitative interview data were transcribed into the Nepali language and thematically analyzed. An inductive coding approach was adopted so that the participants' responses would give rise to the themes. To ensure reliability in the coding, all authors coded the transcripts independently and then compared their codes for agreement. Disagreements were resolved through consensus. By grounding the themes in the actual responses from participants and linking them back throughout their development with both the study's research questions and context, validity was achieved.

The qualitative results were used to explain why and how the quantitative results of the flipped intervention were not desirable. The combination of quantitative and qualitative results allowed for a more comprehensive understanding of the intervention's impact and nuances.

III. Results and Discussion

Quantitative phase

An Analysis of Covariance (ANCOVA) was conducted to compare the effect of the flipped classroom approach on posttest scores, while controlling for pretest scores. The analysis included two groups: an experimental group (flipped classroom) and a control group (traditional instruction). The first stage began with analyzing the pre- and post-learning improvement using the statistical tool ANCOVA.

School A

As depicted by Table 3, the posttest mean score for the control group ($n = 27$) was 7.22 ($SD = 1.87$), whereas the experimental group ($n = 19$) had a lower mean score of 3.74 ($SD = 1.41$).

Table 3. Descriptive statistics for posttest scores by group

Group	Mean	Standard Deviation	N
Control	7.22	1.87	27
Experimental	3.74	1.41	19
Total	5.78	2.41	46

These results indicate that the control group outperformed the experimental group in the posttest. The experimental group performed significantly worse than the control group (mean difference = 3.49, with the control group scoring higher).

An ANCOVA was conducted (See Table 4) to compare the effectiveness of the intervention between the control and experimental groups while controlling for pretest scores. The analysis revealed a statistically significant difference between the groups, F (1, 43) = 47.15, $p < 0.001$, partial η^2= 0.523, indicating a large effect size.

Table 4. ANCOVA summary Table

Source	SS	df	MS	F	Sig.	Partial η^2
Corrected Model	138.53	2	69.26	24.16	0.000	0.529
Intercept	393.65	1	393.65	137.28	0.000	0.761
Pretest	3.05	1	3.05	1.06	0.308	0.024
Group	135.21	1	135.21	47.15	0.000	0.523
Error	123.30	43	2.87			
Total	1800.00	46				
Corrected Total	261.83	45				

The covariate (pretest scores) was not a significant predictor of posttest scores, F (1, 43) = 1.06, p = 0.308, partial η^2 = 0.024. The overall model was significant, F(2, 43) = 24.16, $p < 0.001$, and accounted for approximately 51% of the variance in posttest scores (R^2 = 0.529, Adjusted R^2 = 0.507). These findings suggest that the control group performed significantly better than the experimental group on the posttest, even after adjusting for pretest scores.

School B

The descriptive statistics shown in Table 5 indicate that the students in the control group (n = 19) had a mean posttest score of 31.42 (SD = 7.35), while students in the experimental group (n = 21) had a higher mean posttest score of approximately 45.95 (SD = 15.93). When considering the entire sample (N = 40), the overall average posttest score was 39.05 (SD = 14.46).

These results indicate a noticeable difference in average performance between the two groups, with the experimental (flipped classroom) group scoring higher on average. This comparison does not account for prior differences in ability. Table 5

Table 5. Descriptive statistics

Dependent Variable: Posttest

Group	Mean	Standard Deviation	N
Posttest	31.4211	7.35086	19
Pretest	45.9524	15.92946	21
Total	39.0500	14.45940	40

The ANCOVA conducted has adjusted for such differences using pretest scores as a covariate.

As shown in Table 6, the overall model was significant, F (2, 37) = 104.71, $p < 0.001$, with an R^2 of 0.850, indicating that the model explained 85% of the variance in posttest scores. Pretest scores were a significant covariate, F (1, 37) = 145.76, $p < 0.001$, partial $\eta^2 = 0.798$, demonstrating a strong relationship between students' initial ability and their post-intervention performance.

The effect of the instructional group was not statistically significant at the 0.05 level, F(1, 37) = 3.82, p = 0.058, although it approached significance. The partial $\eta^2 = 0.094$ indicates a moderate effect size, suggesting that the flipped classroom may have had a meaningful, though not statistically significant, impact on student performance.

These findings suggest that pretest scores were a strong predictor of posttest outcomes. The flipped classroom approach showed a potential trend toward improved performance; however, the result is not conclusive, as minimal improvement was observed.

Table 6. Tests of between-subjects effects

Dependent Variable: Posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial η^2
Corrected Model	6929.585[a]	2	3464.792	104.709	0.000	0.850
Intercept	209.874	1	209.874	6.343	0.016	0.146
Pretest	4823.269	1	4823.269	145.764	0.000	0.798
Group	126.548	1	126.548	3.824	0.058	0.094
Error	1224.315	37	33.090			
Total	69150.000	40				
Corrected Total	8153.900	39				

[a]R Squared = 0.850 (Adjusted R Squared = 0.842)

Qualitative phase

The ANCOVA results indicated that the control group outperformed the experimental group. The research team decided to explore the underlying reasons behind this outcome further. To gain deeper insights into this outcome, interviewed six students from the private schools to understand their personal experiences and perceptions of the flipped classroom approach. The qualitative data analysis offers an understanding of how and why the flipped classroom may or may not have supported students' learning. The interview data suggested the following themes:

School A

The following themes were evident from the interviews with students:

Change in the way students learnt

Three students who were interviewed noticed a significant change in how they learned. Instead of just listening to lectures passively, they got involved in discussions, problem-solving, and asking questions. The flipped learning allowed me to be interactive and engaged in class," said a female student. One student said that preparing for the coming Physics class at home was fun, and classroom discussions were more exciting and meaningful.

Resistance to the change

Although the flipped classroom approach was mostly seen as positive by some students, others mentioned difficulties. Two interviewed students mentioned they did not care to watch the materials before class. "I did not like to study something that seemed new to me without the teacher explaining,' said a student, adding, "the approach affected the way I learnt physics in the previous months." While a few students were appreciative of the pedagogical innovation, others still preferred traditional lectures. Some found the flipped method more demanding.

Preference for a blended approach

Most students recommended using both flipped and traditional methods together. They felt flipped learning works well for conceptual understanding of Physics, while traditional lectures are better for new or difficult topics.

School B

The following themes were evident from the interviews with students of School B:

Fun but lacking substance

Several students described the flipped classroom activities as "fun", "enjoyable", or "different from the traditional way of learning," appreciating the potential of the internet resources that could affect the quality of their learning. One student mentioned enjoying the freedom to watch videos at their own pace and coming to class for discussion or group activities. However, many also stated that the materials felt superficial and did not help them fully understand the subject matter. "We talked a lot in class, but I wasn't always sure what we were learning," said one student. One student expressed that while the flipped in-person sessions were more interactive than lectures, he was often confused about the core concepts that he needed to master.

Misalignment between learning material and classroom content

All students interviewed reported that the reading texts and the videos provided by the teacher aligned with what was covered in the classroom. As one student said, "The suggested videos were irrelevant and mostly quite low quality." He added, "I could never finish watching them as they were very long and boring." Another student shared that he did not know "how to read and understand from a video that they watched". "I usually had difficulty in class with understanding parts of the narration in English and did not know what to focus on or how I was supposed to learn from the videos," one participant said.

Barriers to accessing digital learning resources

One-half of the students interviewed indicated that they either did not have access to the internet at home or did not have their personal laptops with which to access or watch the provided materials. “The only equipment in our family is a smartphone that my dad carries. I could not prepare the way the teacher instructed,” said one student. Another noted that approximately half of his classmates come to class unprepared. “To me, the class discussion did not make much sense since I had no clue what the content of the videos was,” he said. He also expressed frustration that the teacher did not seem to sympathize with the digital divide among students. ”I had access to the school’s computer lab, but it was usually busy when I was free,” he explained.

Increased preparation time and disruption of study-style patterns

One quarter of the students interviewed stated that preparing for flipped classrooms took a considerable amount of time, which disrupted their daily routines. “I spent two to three evenings preparing for the upcoming Physics lesson. This prevented me from concentrating on homework for other subjects,” one student said. He added that flipped class attempted to change the way he had always learned. ”I think I was more comfortable having teachers explain the content before asking me to apply it in problem-solving,” he said. He felt that the flipped classroom ”disrupted his way of learning and the process was not particularly helpful.”

Discussion

The study demonstrated the contextual dependence of the flipped classroom model in secondary physics education. In School A, the experimental group performed significantly poorer than the control group, with a large effect size (partial $\eta^2 = 0.523$), suggesting the flipped classroom might have disrupted rather than enhanced the students’ learning in that school. On the contrary, in School B, there was a moderate, non-significant tendency favoring the flipped group, suggesting that the condition might offer more benefits.

Furthermore, in School A, students showed a strong “Resistance to change”. Both schools also had readiness issues because students needed “Increased preparation time” and found their usual study habits messed up. But for School B, the main struggle was access. The theme “Barriers to accessing digital learning resources” proved that many students did not have the devices or internet they needed. Considering the specific problems in School A, such as resistance, time and study disruption in both, and access barriers in School B, is crucial for achieving the expected results of implementing the flipped classroom.

The qualitative findings revealed that students’ readiness for self-directed learning (manifested as resistance to change in School A and increased preparation time in both schools) and equitable access to technology (a significant barrier in School B) were critical factors influencing the outcomes. These findings align with current literature indicating that the flipped classroom is not a universally effective solution. The success of the flipped classroom varies significantly across contexts.

Literature indicates that the success of flipped learning depends on varied features, such as student motivation, teacher facilitation skills, alignment of materials, and digital infrastructure [14, 18]. In School A, students complained about the new learning model because most found it uncomfortable to learn new content on their own. Additionally, students complained of being overwhelmed by a lot of expectations to meet before class. This finding aligns with the conclusion made by O'Flaherty and Phillips [2], who noted that flipped learning might be very cognitively demanding for students accustomed to traditional, teacher-led instruction.

Further issues emerging from student interviews at School B were that the teacher did not prepare the pre-class materials with care and precision. This finding is reinforced by the recent insistence on the part of researchers that the quality and instructional design of the pre-class materials is what determines the effectiveness of flipped classrooms [27, 28]. Students complained that when videos were either too long or made no sense, they did not relate to what was being taught. Students mentioned that they lost interest and got confused in class due to the lack of precision in instruction. This finding was reinforced by the conclusions of Talan and Gulsecen [17], who reported that the language of the videos, incomplete scaffolding, and lack of interactive ICT resources are likely reasons for the failure of the flipped classroom approach.

Another central theme that emerges from qualitative data is the divide in access to digital equipment and the internet. Half of the students who were interviewed indicated a significant lack of access to digital devices or a reliable internet connection at home. This digital divide remains one of the leading barriers faced in most educational settings, especially in low and middle-income countries like Nepal. This is truer when it comes to rural schools such as School B in this study.

These results are remarkable for the educational context of Nepal. The rural public school students were more accepting of the flipped learning method despite their lack of access to digital resources and infrastructure. Interview data show that while these students indeed had some barriers to accessing devices and internet connectivity, they all found the approach fun and participatory. This finding is in line with research findings of Valtonen et al. [25] and Pun [20], who argued that under-resourced students are likely more adaptable and willing to accept innovations in education and are more willing to experiment with new methods.

In contrast to students from a private school, who had access to better digital tools and infrastructure, they preferred teacher-centric teaching. These students were likely unwilling to apply independent self-study approaches in the flipped classroom and had difficulty adjusting to the flipped approach. This indicates that conditioning may limit the receptivity of these high-achieving private school students towards pedagogical innovations. It has also been seen in Nepali studies that private students face highly structured, rigid-exam-oriented instruction, which impedes autonomous learning with flexibility [21]. Their dissatisfaction may not originate from the flipped classroom design itself but from a mismatch between the approach and their schooling experiences before now.

Such observations correspond to findings in many parts of the world regarding flipped learning: its success is determined by access to technology, learning cultures, expectations, and instructional histories of students [6, 14]. The qualitative data also uncovered other challenges, such as misalignment of pre-class materials used in in-class instruction, most especially in School B. According to students, some of the videos were long, irrelevant, or confusing, particularly when delivered in English or missing interactive scaffolding, a barrier common in EFL contexts [16]. Another pertinent issue was digital inequality, especially among rural pupils. Even in school B, several students were open to change, despite lacking personal devices or internet at home, but were able to share resources or rely on those available at school. This concurs with literature highlighting the interrelation between pedagogical innovations and digital equity in particularly low-resource contexts [18, 19]. Still, the willingness of rural public students to leap into something different often undersells one of its deeper cultural strengths: flexibility in pedagogy among underserved learners.

The flipped-classroom model also has potential, particularly in observing the environmental context and providing rich instructional support. These findings challenge the assumption that resource-rich students will naturally benefit more from innovative methods, suggesting instead that mindsets, openness to change, and instructional coherence are equally important as accessing digitally theory-rich resources.

Further, a significant number of students stated that the flipped classroom approach demanded extra time for preparation, and it disrupted their established study habits. Such complaints have been recorded by several other studies, too. Yilmaz and Baydas [6] stated that though the flipped model aims to promote active engagement from the students, learner-centeredness, students may experience increases in cognitive load. The researchers also argued that students require greater time management and self-regulation skills if the flipped classroom is to make an impact. Zainuddin et al. [29] conclude that the prerequisite for a flipped classroom is likely to cause frustration among pupils and result in poorer learning outcomes if there is no adequate support and scaffolding.

IV. Limitations and Future Directions

This study has several limitations: a) the topics covered in the flipped classroom intervention were different between the two schools (electrostatics in School A and force/pressure/heat in School B), which might have influenced the outcomes, b) the duration of the intervention was only three weeks and the implementation hours varied between the two schools, c) the sample size was limited to two schools, d) the student's sample was not randomized but selected purposely, e) differences in the grade levels, teacher practices, and instructional resources are not taken into account for analysis. Future research could explore the implementation of flipped classrooms over a more extended period in diverse schools, across a variety of subjects, not just Physics. It is also important that controlling for topics taught at all participating schools is key to a better research design. In addition, future studies should examine the role of teacher training and digital pedagogy skills in shaping the success of flipped instruction.

V. Conclusions

Overall, this study suggests that while the flipped classroom model holds potential benefits, its effectiveness depends on the fulfillment of several preparatory conditions. The success of this approach is context-dependent and influenced by factors such as the quality and alignment of instructional materials, students' readiness for self-directed learning, and equitable access to technology. The findings highlight that just adopting flipped learning without considering students' prior learning experiences and the availability of essential resources can hinder rather than enhance learning outcomes. This study emphasizes the need for thoughtful planning and the inclusion of support structures that address contextual challenges to ensure that flipped learning can truly improve student achievement.

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