World Journal of Vocational Education and Training
2024 Vol. 6, No. 1, pp. 25-35
ISSN: 2690-280X
DOI: 10.18488/119.v6i1.3800
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Research on applying flipped classroom and digital learning to high school programming courses

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Article History
Received: 28 April 2023
Revised: 21 June 2024
Accepted: 2 July 2024
Published: 8 July 2024

Keywords
Digital learning
Flipped classroom
High school programming
Learning effectiveness
Learning satisfaction
Student engagement.

ABSTRACT

The objective of this study is to investigate how flipped classrooms affect education in high school programs. Although many studies have pointed out that flipped teaching can improve the learning experience and can evaluate learning effectiveness through classroom activities, it may also make it difficult for teachers to grasp students' learning status and behavior, and flipped teaching is used in high school programming course recognition and satisfaction Empirical research is somewhat lacking. Accordingly, this research applies the flipped teaching method to high school programming courses and gathers data on students who watch instructional videos. Through research data analysis, it is found that 51% to 93% of students will actively watch the designated instructional videos before class, and some students will repeat Watch the video (1.3 to 1.8 times), and most students will watch it again during the group project design. In addition, most students have the habit of adjusting the video speed to self-regulate their learning (1.4 to 1.5 times). The questionnaire results indicate that most students prefer the flipped classroom learning method (3.48 to 4.01 points). Through this study, we understand the students' mode of digital learning in programming courses, and we know that flipped classrooms can improve the learning satisfaction of programming courses.

Contribution/Originality: This study contributes by demonstrating the effectiveness of flipped classrooms in high school programming courses, showing that it enhances students' interest in learning, professional knowledge levels, and ability to integrate knowledge. It suggests that teachers adopt this method to improve teaching effectiveness.

1. INTRODUCTION

Programming education courses are slowly becoming more important as information and communication technology advances (Kanemune, Shirai, & Tani, 2017; Robins, Rountree, & Rountree, 2003; Silva, Mendes, & Gomes, 2020). In learning programming, aside from teaching basic syntax, developing logical thinking and problem-solving skills is also crucial (Robins et al., 2003; Xu, 2006). Through practical implementation, students can understand how to write and construct a comprehensive and executable data analysis logic, thereby cultivating their ability to independently complete analytical projects. The traditional one-way lecturing approach of programming education can make it challenging for learners to combine theoretical knowledge with practical application, resulting in challenges. The passive listening learning method is not effective in developing learners' logical thinking and problem-solving skills. To achieve high grades, learners may often memorize answers and depend on question banks, but these tendencies can lead to a decrease in learning outcomes (Lahtinen, Ala-Mutka, & Järvinen, 2005). Traditional programming instruction emphasizes the explanation of basic syntax and concepts.

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Due to limited class time, instructors must strike a balance between progressing through the curriculum and providing opportunities for practical exercises, resulting in fewer opportunities for students to practice hands-on during class. To turn these solutions into a practical process of coding, students must integrate programming skills with critical thinking and problem-solving considerations (Shih, 2018). It has been demonstrated by research that programming courses require coherence. If students fall behind early in the course or misjudge their understanding of course content due to limited practical opportunities, they may struggle to successfully complete more challenging exercises later on, leading to a vicious cycle of lacking confidence and finding programming uninteresting (Tan, Ting, & Ling, 2009). Bergmann and Sams (2012) assert that the flipped classroom's development today is facilitated by advancements in instructional technology, which facilitate an active learning approach for teachers, in response to the challenges mentioned above. The core value is to give students the power to control their learning. According to researchers' past experiences with flipped classroom teaching, teachers have attempted to help students learn syntax, functions, and execution processes by using e-books before and after class. Nonetheless, they are still faced with multiple challenges. It is challenging to provide individual guidance for students who struggle to keep up with the pace and require thoughtful consideration and exercise completion while adhering to the teaching schedule. Students who lack focus may struggle to grasp all the course content in real-time, leading to missed important practice opportunities during class. Lastly, considering the evident differences in the foundational abilities of each student, some may not have sufficient time to fully absorb the content in the first half of the course, leading to difficulty in keeping up with the subsequent curriculum. This teaching method is perceived by students as passive and lacking in interaction due to these factors. Learning programming was initially exciting, but they became disinterested due to feelings of frustration and difficulty during the process. The efficient utilization of learning time is a benefit of digital learning that has been demonstrated by research (Bishop & Verleger, 2013). The future development of programming education research could be influenced by its application in practical research on flipped classrooms in high school programming education. Therefore, this instructional practice research aims to apply the flipped classroom and digital learning methods, enabling students to learn at their own pace and increasing opportunities for hands-on programming, to address the issues of insufficient time for course practical exercises and uneven basic skills. The study will conclude with a satisfaction survey at the end of the semester, utilizing a digital learning platform to collect data on video views and online assessments, understanding students' patterns of self-directed learning as a basis for improving digital materials and teaching methods.

2. LITERATURE REVIEW

2.1. The Application of Flipped Classroom in Senior High School

Flipped classroom instruction has increasingly become popular in recent years as an innovative teaching strategy that changes traditional teaching methods. The main feature of this model involves reversing the conventional instruction process. In a flipped classroom, teachers typically provide pre-recorded instructional videos as preparatory materials for students to view beforehand. Class time is then focused on teacher-student interactions, discussions, Questions and Answers (Q&A) sessions, and practical exercises, which aim to foster students' critical thinking abilities and help them apply theoretical knowledge to real-world situations. Furthermore, student feedback at the end of class serves as an essential metric for assessing learning satisfaction.

Research has been conducted on the application of flipped classrooms in high school history courses, where teachers assigned relevant articles for students to study independently before class. During class, teachers used these self-directed learning materials to guide instruction, facilitated group discussions, addressed questions in real-time, and directed the learning focus of each group, evaluating outcomes through the completion of learning sheets (Hsieh, 2018). Another study examined a high school technology course where teachers employed YouTube videos on assembling and testing solar-powered cars to promote self-directed learning. In the classroom, students worked

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in groups to assemble the cars, engaging in self-exploration and problem-solving, with learning outcomes assessed through a competitive format (Lin & Tsai, 2020). Additionally, some courses emphasized the importance of student input and encouraged active class participation, granting students autonomy over their learning while teachers provided support (McLaughlin et al., 2014). In summary, the implementation of flipped classroom practices in high school education involves two stages: pre-class and in-class. During the pre-class stage, students engage in self-directed learning by watching pre-prepared instructional videos or reading supplementary materials, which fosters autonomy and learning habits. In-class activities typically include group discussions, Q&A sessions, hands-on exercises, and assessments. These activities are designed to encourage the application and reflection of acquired knowledge, thereby enhancing learning satisfaction and effectiveness. Before adopting flipped classroom methods, teachers should evaluate the course content, student engagement levels, and interactive classroom dynamics to determine the suitability and optimal implementation strategies for the specific course.

2.2. Evaluation of Learning Outcomes in Flipped Classrooms

The literature on flipped classrooms in secondary education highlights that flipped classrooms positively influence learning experiences, motivation, and outcomes compared to traditional teaching methods. Numerous studies have shown significant improvements in learning outcomes with the use of flipped classrooms. The effectiveness of flipped teaching can be analyzed through objective effectiveness assessment, subjective effectiveness assessment, and satisfaction assessment. The assertion that flipped teaching enhances student performance is backed by literature, showing an improvement rate of about 15% to 30% (Tu, 2019). For instance, Lin and Tsai (2020) integrated flipped teaching into a high school biology curriculum focusing on photovoltaic technology related to solar-powered cars. They found a significant correlation between flipped teaching and student learning outcomes, achieved through self-directed exploration. Another recent study compared the learning outcomes of a high school information technology course between an experimental group using flipped learning and a control group using traditional lectures. The results indicated that flipped teaching improved learning outcomes in the information technology course (Hung, Huy, Thanh, Loc, & Tien, 2022).

To evaluate subjective effectiveness, a vocational nursing science class utilized flipped teaching in anatomy and physiology, finding that it positively impacted students' attitudes towards the model and improved learning effectiveness (Chuang, 2018). In another study, Wang, Chen, and Tseng (2012) employed a quasi-experimental design to investigate how flipped learning affects high school students' attitudes and the integration of robotics into programming courses.

Through interviews, they found that flipped teaching enhanced self-directed learning, learning attitudes, interactions, problem-solving abilities, and knowledge construction. Deng (2016) conducted an experimental study on flipped teaching in mathematics, focusing on learning motivation and outcomes. The study revealed that flipped teaching positively influenced students' learning motivation, active thinking, problem exploration, independent solution-seeking, task completion, and classroom activities.

Flipped teaching helps students develop self-directed learning habits and the ability to discuss and solve problems with peers. Furthermore, foreign scholars used the Likert five-point scale to investigate students' views on flipped teaching, revealing that up to 96% of students agreed or strongly agreed that watching course content videos before class was important, and 90% of students agreed that the video content was related to the themes of classroom activities (Pierce & Fox, 2012). In previous research, it was found that students have a strong preference for peer collaboration in class and view interactive learning methods as beneficial for improving learning effectiveness (McLaughlin et al., 2014). To sum it up, flipped teaching increases students' achievement in learning, involvement, attitudes towards cooperative learning, self-efficacy in online learning, learning outcomes, and course satisfaction.

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2.3. Evaluation of Learning Outcomes and Satisfaction in the Application of Flipped Classroom in Programming Courses

According to relevant literature on flipped education in high schools, the introduction of flipped classrooms has a significant impact on improving learning outcomes. A controlled experimental research approach has confirmed the advantages of implementing flipped classrooms in programming education.

In one study, 127 students were observed, with 70 choosing flipped classroom learning and the rest opting for traditional lecture-based methods. The research found that on the final exam, 81% of students using the flipped classroom approach passed, while only 60% of students using traditional methods failed. Furthermore, 58% of flipped classroom students achieved excellent grades, while only 32% of traditional classroom students did so. By using flipped teaching, the percentage of students passing the course increased and the number of high-achieving students doubled (Jonsson, 2015). A U.S. school's beginner programming course uses pre-recorded instructional videos as their primary teaching tool. The course uses a method of teaching that involves explaining concepts before engaging in practical exercises, and is delivered by three experienced instructors. The first instructor spends a relatively brief lecture time highlighting both correct and incorrect examples in student assignments, answering related questions, and briefly introducing new concepts. In the end, students participate in the day's practical exercises and ask questions. The second instructor spends the most time lecturing, giving detailed explanations for each concept, followed by hands-on practice by students. The third instructor's style is between the two, but they make slides beforehand for a short lecture prior to class. According to a survey on students' pre-class video watching and reading habits, 74% of students spent the longest time watching videos from the first instructor, followed by the third instructor at 68%, and the second instructor the lowest at 34%. Furthermore, students were generally of the opinion that more instructional videos made it easier for them to comprehend course content, with a ratio of 4:3:3. The ratio of preference for this teaching method was 3:3:2. In programming assessments, the students of the first instructor performed the best, obtaining the highest average score (82). The students of the second and third instructors averaged 73 and 78 in comparison. According to this finding, pre-recorded videos before class and minimizing traditional lecture-based teaching can more effectively assist students in learning programming (Reges & Stepp, 2020). The traditional teaching model allows teachers to monitor their students' learning progress in real-time and modify the course content accordingly. Flipping teaching is about shifting learning activities from the classroom to pre-class, allowing students to self-control their learning pace. Teachers find it hard to closely observe students' learning behaviors during self-directed learning in the classroom because the focus is mostly on assessing learning outcomes through activities. Some studies have indicated that there is still a lack of research on improving programming teaching effectiveness in the flipped classroom, especially in senior high school education (Hung et al., 2022). Flipped classrooms have little research on how students learn (Zeng & Shi, 2021). The aim of this study is to analyze the backend data of students who watch instructional videos to gain a comprehensive understanding of their learning behavior during self-directed learning. These analytical results will be essential reference points for modifying course videos in the future.

3. RESEARCH DESIGN

3.1. Curriculum Design

The study surveyed first-year students at a national senior high school in Taiwan for 11 weeks, with a student population of 71. There are 48 male students and 23 female students in total. Flipped classroom teaching was experienced by approximately half of the students during their junior high school years. The course is a required subject in senior high school, and it is scheduled for two consecutive classes each week. In the first week of the academic year, the researcher provided a detailed explanation of the teaching approach for the course and the purpose and methods of the study to the students. The collection of data, including questionnaire surveys, observation of course video recordings, and test data, was done after obtaining consent from all students. The goal of this study is to explore the 'Programming' course and develop students' abilities in combining programming and

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computational thinking to solve problems more effectively. To overcome the challenges in programming courses, where the volume of practical exercises can hinder in-depth learning and result in suboptimal learning outcomes, we employed the flipped classroom teaching method in the 'Programming' course. The learning process is divided into three main stages in this teaching method: pre-class preparation, in-class practice, and post-class application.

In the pre-class preparation phase, students are expected to learn the content of course videos on a digital learning platform by themselves. The course content is derived from the textbook and formatted into presentation slides. The teacher employ screen recording software coupled with voice narration to create instructional videos. The average duration of each video segment is maintained at approximately 12 minutes or less. The teacher strives to provide immediate feedback to students who pose questions on the digital learning platform during self-directed learning. In order to measure students' understanding and application abilities about the pre-assigned video content, we implemented an interactive feedback system for in-class quiz activities. Students are required to complete relevant tasks and upload their answers to the digital learning platform in these activities, whether conducted individually or in small groups. There are three kinds of practice questions that can be used: multiple-choice, fill-in-the-blank, and group projects. The design of the first two types encourages students to thoroughly preview the content before class, drawing from the emphasized key points in the videos, with the opportunity for immediate answering and feedback. Group projects that are more advanced present a certain degree of difficulty and require team members to work together to solve problems through discussion.

3.2. The Research Process and Data Analysis

The main purpose of this study is to investigate students' satisfaction with the learning process through a questionnaire survey, and simultaneously analyze in-depth the pre-learning behaviors and post-independent review behaviors resulting from the implementation of flipped classrooms. To accomplish this goal, we utilized the digital learning platform's course video viewing data extensively. For a more in-depth analysis, we segmented the instructional videos into eight thematic units based on their content and collected information on the viewing data for each video within these units, including the number of views, average viewing time, and average viewing speed. By gathering this data, we can gain a deeper understanding of how flipped classrooms affect students' learning patterns. It is expected that this information will assist teachers in more precisely assessing students' learning conditions and subsequently improving the content of course videos and interactive teaching content in the classroom. Figure 1 illustrates the process of conducting research and analyzing data.

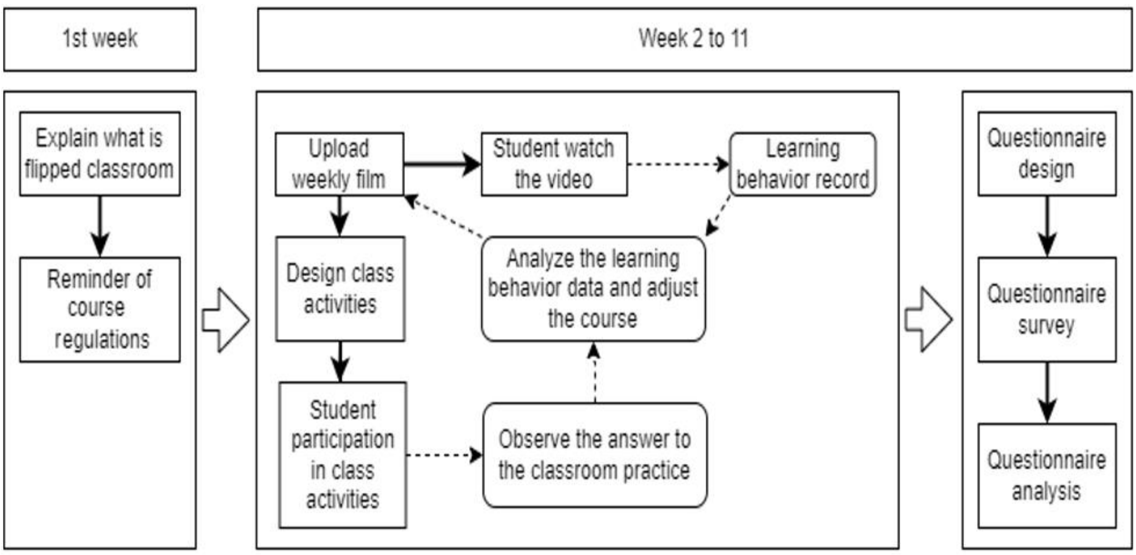

Figure 1. The research process and data analysis.

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3.2.1. Analysis of Student Video Viewing Learning Behaviours

To gain a deeper understanding of students' learning behaviors, this study focuses on whether students watch the designated course videos before class, if they revisit the videos, and whether they can autonomously regulate their learning pace. We focus on whether students review course videos while working on group projects and identify the most frequently watched videos. The digital learning platform provides data on course videos for the study, including metrics such as 'viewing count' and 'average viewing time'.

First, we categorize the videos into eight main thematic units. The 'viewing count' indicates the number of times each video is clicked by students, which is a key metric for assessing the videos' popularity. The 'non-repeated student viewing count' shows how many times a student clicks on a specific video, counting only once per student even if the student clicks multiple times. The 'average non-repeated student viewing count' is calculated by dividing the non-repeated view count by the number of videos in that thematic unit. Additionally, 'the average views per student' is obtained by dividing the total view count by the non-repeated student view count, providing insights into how often students revisit videos. The 'pre-class viewing count ratio to all students' is determined by dividing the average non-repeated student view count by the total number of participants, helping to understand students' engagement in pre-class previewing. Finally, the calculation of 'video viewing speed' involves dividing the total duration of videos in a thematic unit by the average viewing time per student, offering insights into students' autonomous regulation of learning pace.

3.2.2. Questionnaire Analysis

To examine students' motivation and perceptions regarding the implementation of flipped teaching in the information technology course, we used the Likert five-point scale to assess their viewpoints. Four key dimensions are covered by the questionnaire, including course material design, course activity design, digital teaching platforms, and learning motivation. The scoring process involves five options for each question: 'Strongly Agree,' 'Agree,' 'Neutral,' 'Disagree,' and 'Strongly Disagree,' with scores ranging from 5, 4, 3, 2, and 1 for each choice.

4. RESULTS

4.1. The Behavioural Patterns of Students Watching Course Videos

The digital learning platform exported learning records for 71 participating students after the 11-week flipped classroom program. The analysis of course video viewing records is presented in Table 1, revealing that students had a higher 'non-repeated viewing count' for course videos related to 'Variables and Expressions' (93%) and 'Algorithm Concepts and Implementation' (84%) in the pre-class viewing phase. Furthermore, the average number of times students rewatched the videos was between 1.3 and 1.8. Additionally, 51% to 93% of students took part in pre-class video previewing. Each student set an average video playback speed of 1.41 to 1.51 times.

Furthermore, this study aimed to understand students' review behavior, including videos, during the group project design. The analysis of video viewing data from the five group project implementation sessions that lasted 11 weeks is shown in Table 2. It was observed that 19% to 51% of students reviewed course videos for content review, with 'Sequential Structure and Selection Structure' (51%) and 'Variables and Expressions' (45%) having the highest 'non-repeated viewing counts. ' The average number of times each student rewatched the videos during this phase ranged from 1.1 to 1.4, and the average video playback speed set by each student ranged from 1.05 to 1.23 times.

To summarize, it is apparent that students frequently rewatch course videos 1-2 times prior to class, with an average video playback speed of approximately 1.5 times. During the process of designing group projects, students often rewatch course videos 1 to 1.5 times, with an average video playback speed of approximately 1.25 times. Students tend to lower their video playback speed during the group project phase as there is a decrease in the number of repeated viewings.

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Table 1. The course video viewing data after the implementation of flipped classroom.

Course video titles	Number of videos	Viewing count	Non-repeated viewing count	Average non-repeated viewing count	Average viewing count	Proportion of pre-viewing counts to all students	Total duration of videos (Seconds)	Average viewing time per student (Seconds)	Video playback speed (Times)
Introduction to programming languages	2	143	113	56.5	1.3	80%	929	655	1.42
Variables and expressions	6	524	396	66.0	1.3	93%	1879	1261	1.49
Sequential structure and selection structure	4	346	217	54.3	1.6	76%	462	320	1.44
Repetition structure	5	385	211	42.2	1.8	59%	1135	785	1.45
Implementation and application of arrays	5	440	273	54.6	1.6	77%	1361	928	1.47
Algorithm concepts and implementation	9	768	538	59.8	1.4	84%	3781	2501	1.51
Fundamental concepts and applications of trees	4	201	147	36.8	1.4	52%	1770	1188	1.49
Fundamental concepts and applications of graphs	4	190	144	36.0	1.3	51%	937	664	1.41

Table 2. Course video viewing data during group project period.

Course video titles	Number of videos	Viewing count	Non-repeated viewing count	Average non-repeated viewing count	Average viewing count	Proportion of pre-viewing counts to all students	Total duration of videos (Seconds)	Average viewing time per student (Seconds)	Video playback speed (Times)
Variables and expressions	6	252	193	32.2	1.3	45%	1879	1523	1.23
Sequential structure and selection structure	4	160	145	36.3	1.1	51%	462	403	1.15
Repetition structure	5	187	156	31.2	1.2	44%	1135	1078	1.05
Implementation and application of arrays	5	142	101	25.3	1.4	36%	1168	1013	1.15
Algorithm concepts and implementation	9	167	119	13.2	1.4	19%	3781	3561	1.06

4.2. The Results of the Questionnaire Survey Analysis

The questionnaire had 11 items categorized into four main dimensions: course material design, course activity design, digital learning platform, and learning motivation. The use of these dimensions was made to conduct a survey on the satisfaction of students with the course. The Cronbach's α value for this questionnaire was found to be 0.965 after reliability analysis, which indicates excellent overall reliability. An effective response rate of 91% was achieved by administering the survey through an online questionnaire, with 71 surveys distributed and 65 collected. Table 3 displays the item scores.

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Table 3. Satisfaction survey on the implementation of flipped classroom teaching.

Aspects	Survey questions	Average
Course material design	The teaching method of this course can stimulate my interest in the subject	3.54
	The content of the videos in this course has been helpful for my learning effectiveness	3.53
	The difficulty level of the course materials in this course is appropriate and has been helpful for my learning effectiveness	3.48
	I can learn the knowledge and skills I want from this course	3.63
Course activity design	The learning activities arranged in this course can motivate me to learn actively	3.47
	The assessment content in this course is helpful for my learning effectiveness	3.61
	The arrangement of learning activities in this course accurately reflects my learning performance and level	3.71
Digital learning platform	I like this kind of learning method with pre-class preview	3.51
	I think the digital learning platform easy to operate	3.69
Learning motivation	I believe this course is helpful for my future education and career	4.01
	I think this course can enhance my interest in learning	4.00

According to Table 3, in terms of course material design, the average satisfaction accounted for 3.54. In terms of course activity design, the average satisfaction accounted for 3.60. In terms of digital learning platforms, the average satisfaction accounted for 3.60. In terms of learning motivation, the average satisfaction accounted for 4.01. Overall, it shows that most students agree with the learning method of applying flipped teaching in programming courses.

5. FINDINGS

Based on the analysis of the video viewing data, it can be observed that the majority of students proactively watch the assigned instructional videos before class, and many students repeatedly watch these course videos. Additionally, most students tend to watch the instructional videos at an accelerated pace. According to the researcher's observation, 1.5 times the video playback speed is considered the limit for clear comprehension, and the data analysis indicates that most students fall within this speed range. This suggests that students have the ability to adjust their learning pace to meet their needs and improve learning efficiency. The average number of views per student indicates that videos about programming concepts like sequential structures, selection structures, looping structures, array implementation, and application are watched repeatedly. Similarly, during the design phase of the group project, some students revisit videos on relevant topics. The study results also show that quiz activities following the course videos trigger repeated learning behavior among students. Moreover, the analysis of survey results indicates that the majority of students have high motivation for this flipped learning approach and consider the content quality of the course videos to be crucial. Therefore, based on the combined observations and survey findings, it can be reasonably inferred that delivering instructional content for pre-class viewing allows students to learn at their own pace and increases their engagement in pre-class independent learning. The data analysis of course videos suggests that students are highly interested in instructional units related to programming implementation. Instructors who use code to teach programming logic concepts and apply them through group project designs are appreciated by them. By shifting instructional content to pre-class viewing, instructors can provide more hands-on practice opportunities, making in-class time more valuable and flexible. In conclusion, based on the above observations, we have reason to believe that the flipped teaching method provides students with more time and opportunities to understand and apply what they learn, thereby enhancing their overall satisfaction with the learning experience.

The analysis of course video viewing data reveals that videos in the conceptual category (e.g., programming language introduction, basic concepts, and applications of trees, basic concepts, and applications of graphs, etc.) have a lower average view count. This may be attributed to the fact that this type of course content covers fundamental programming logic concepts applicable to various programming languages, and students in the class have been

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exposed to these concepts during their middle school years, resulting in a lower average view count. Analyzing the course video viewing data during the group project period as presented in Table 2, it is observed that the average view count for "Array Implementation and Application" and "Algorithm Concepts and Implementation" is higher. It can be inferred that learning topics such as arrays and algorithms are perceived as more challenging by students, involving higher-order cognitive skills like problem decomposition, pattern recognition, abstraction, and algorithm design. The higher average view count reflects the advanced cognitive abilities required for programming learning (Selby, 2015) As shown in Table 1, both the average view count for unique students and the ratio of pre-class views to total views decrease as the course progresses. This trend supports the findings of Zeng and Shi (2021) who suggest that instructors might consider adjusting the pacing of early course content and moderating the workload in later stages. Furthermore, it has been observed that the video viewing speed during the group project period is significantly lower than the average viewing speed over the 11 weeks. This suggests that group project activities encourage students to learn at a slower pace to gain a deeper understanding of the content. The analysis indicates that video viewing patterns vary across different course topics and stages, underscoring the importance of instructors customizing the course pace and content difficulty. The slower video viewing speed during group project periods implies that these activities foster a more thorough comprehension of the learning material.

6. CONCLUSION

This study's aim is to examine the learning behavior and satisfaction of high school students in a flipped classroom setting for programming courses. Following a comprehensive analysis of data from student video views and survey results, the following conclusions were drawn.

The flipped classroom approach for programming courses has a positive attitude among high school students and they demonstrate self-directed learning skills. The data indicates that the majority of students can complete the assigned instructional video viewing before class, with some even watching the same video multiple times, especially during group project periods for a review of relevant instructional content. Students are embracing the video teaching mode and transitioning from a passive learning approach that relies on teachers to a proactive self-learning approach before class. During group design activities, students demonstrated their ability to complete programming projects and displayed behaviors indicative of self-directed learning in the classroom. This aligns with the survey results regarding satisfaction with flipped classroom instruction, where a majority of students recognized the effectiveness of pre-watching videos before engaging in in-class exercises as highly beneficial for learning information technology courses. Additionally, the analysis of video viewing speed reveals that the majority of students watch instructional videos attentively and adjust the playback speed appropriately. Some students utilize the replay feature during group project design to watch key instructional videos multiple times, indicating that most students reflect on the teacher's assigned exercises after class, even replaying sections of the teacher's instructional code to deepen their understanding.

The flipped classroom method is an effective way to enhance student learning satisfaction in high school programming courses. According to survey analysis, students generally have a higher level of acceptance and satisfaction with the flipped classroom. The flipped classroom indeed encourages students to actively participate in class activities, improving their learning quality, effectiveness, and satisfaction. Implementing the flipped classroom method in teaching practices makes the content more flexible and in-depth, allowing teachers to guide concept application more thoroughly in class, offering more opportunities to understand and address students' learning difficulties. This teaching method is widely agreed upon by students as it increases their interest in learning, raises their professional knowledge level, and enables them to integrate and apply the acquired knowledge. Using the flipped classroom approach is a valuable option for teachers in their teaching work, and it is suggested that they make the most of it.

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7. LIMITATIONS

While the digital learning platform used in this study incorporates a comprehensive account control mechanism to prevent simultaneous access from multiple devices or cross-screen learning behavior, there are still some limitations in the data analysis of this research. The analysis is limited to presenting and examining patterns of student video viewing behavior. Despite the overall satisfaction exceeding dissatisfaction in various dimensions according to the questionnaire, we cannot fully comprehend repetitive viewing behaviors when students struggle to grasp the content (e.g., when the video is paused, students' thinking time, inability to capture instances of students skipping or replaying segments). Conducting in-depth interviews is necessary to gain a complete understanding of other reasons for changes in student learning behavior. Additionally, the effectiveness of this study's instruction may differ depending on the learning styles and preferences of each student. The research did not explore these differences in depth.

Funding: This study received no specific financial support.
Institutional Review Board Statement: The Ethical Committee of the Asia University, Republic of China has granted approval for this study on 17 November 2022 (Ref. No. 1111117253).
Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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