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Enhancing intelligent connected vehicle technology instruction through flipped classroom pedagogy: A qualitative inquiry

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Abstract

This study explores the implementation of the flipped classroom model in teaching the intelligent connected vehicle (ICV) technology course and investigates its effect on student engagement, learning effectiveness, instructional strategies, and curriculum innovation. A qualitative descriptive research design was adopted, involving in-depth interviews with five experienced teachers and ten students from the Shaanxi Polytechnic Institute's Automotive Intelligence program. Participants were selected through purposive sampling based on defined eligibility criteria. Semi-structured interviews focused on experiences, perceptions, challenges, and instructional practices within the flipped classroom setting. Thematic analysis was conducted to identify recurring themes and patterns in the data. Results reveal that flipped classrooms significantly enhanced student motivation, classroom interaction, and understanding of complex ICV concepts. Critical success factors included students' prior knowledge, availability of technological resources, level of self-discipline, and the adaptability of teaching strategies. Teachers emphasized the importance of continuous student feedback in refining instructional content and delivery. Based on the findings, a structured "dual-subject, three-stage" teaching path was developed to promote personalized and active learning. However, challenges such as limited technical infrastructure and the learning difficulties of students with low self-regulation were also highlighted. Findings are limited to a single institution and specific course context, which may affect generalizability. Future research could incorporate quantitative or mixed-methods approaches and examine broader applications across various disciplines and educational settings. Nonetheless, the study offers meaningful insights into effective pedagogical strategies for teaching emerging technologies using the flipped classroom model.

Keywords: *flipped classroom, intelligent connected vehicle (ICV), active learning, instructional design, student engagement, technology-enhanced learning*

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1. Introduction

The development of Intelligent Connected Vehicle (ICV) has brought great changes to the automotive industry and is an important part of building a transportation power. In order to meet the current demand for related technical talents in the development of automotive technology, colleges and universities have put forward higher requirements and attention to the ICV technology courses. As a multidisciplinary emerging technology, the course is an interdisciplinary course covering sensing technology, communication and network technology, navigation and positioning technology, decision-making and control technology, among others. Traditional teaching is teacher-centered, lacks interaction, struggles to accommodate student differences, and fails to effectively utilize technological tools. Therefore, it is difficult to ensure teaching effectiveness using the traditional teaching model. Given the characteristics of the course, which is broad in scope, theoretically intensive, and challenging in practice, a flipped classroom teaching model is adopted. This is combined with a blended teaching approach that integrates online and offline learning, merges theory with practice, and incorporates knowledge transfer, skills development, and quality education (Li & Li, 2019).

In the context of the rapid development of information technology, the integration of technology into teaching has received unprecedented attention. The flipped classroom is one of the current focal points of teaching reform. It involves reversing the traditional teaching sequence to maximize student agency and promote deep learning. As a highly effective teaching model, it aims to enhance students' abilities to analyze and solve problems, thereby fostering in-depth learning and sustainable development (Zhang et al., 2024; Zhao, 2022). The flipped classroom reallocates time inside and outside the classroom, shifting decision-making power from teacher to student. Its core distinction from traditional classrooms lies in the transition from a "teach before you learn" model to a "learn before you teach" approach. While flipped classroom offers many advantages (Laswadi et al., 2023), this does not imply that conventional classroom teaching should be disregarded.

Therefore, this paper investigates the application of the flipped classroom model in the ICV technology course and analyzes the key factors influencing its implementation. It aims to explore the effectiveness of flipped classroom instruction in enhancing student learning within this technical discipline. Additionally, a teaching pathway is proposed to address the unique challenges presented by the ICV technology course. The overarching goal is to promote

effective teaching practices, support independent learning, increase student engagement, and meet personalized learning needs for improved educational outcomes.

Building on this foundation, the significance of the study lies in its response to the instructional challenges posed by emerging multidisciplinary content such as ICV technology. By applying the flipped classroom model, the study seeks to enrich classroom instruction, boost student interest, unlock individual potential, and foster both innovation and practical skills. This approach also aims to support students' holistic development, particularly in information literacy, and to cultivate more independent and reflective learners.

To gain a comprehensive understanding of its impact, the study examines the primary factors affecting the flipped classroom model through teacher interviews and evaluates its effectiveness in promoting student participation and engagement through student interviews. These findings provide practical insights for educators, serving as a guide for improving classroom implementation and avoiding common pitfalls. Furthermore, the proposed teaching path not only helps teachers integrate information technology into their instructional practices but also supports their professional growth. In addition, it contributes to the broader educational landscape by promoting equitable access to high-quality learning resources (He, 2024).

Given its contributions to pedagogy, educational equity, and curriculum innovation, this research holds both theoretical and practical significance in advancing the effective use of flipped classrooms in ICV technology and similar emerging fields.

2. Literature Review

The flipped classroom originated from the "Upside-Down Classroom" created by Lager, Pratt, and Tria (Gao, 2021). It has transformed the traditional teacher-centered teaching model by integrating technology to enhance the learner's experience to varying degrees. This innovation in teaching methodology has led to the increasingly widespread adoption of the flipped classroom in education. It is now recognized as a widely accepted and innovative pedagogical approach designed to enhance student learning by shifting the traditional instructional paradigm (Cevikbas et al., 2022; Jdaitawi, 2019; Laswadi et al., 2023; Ismatovna, 2022). Therefore, implementing the flipped classroom model and employing active learning methods in education have become necessary steps toward improving teaching effectiveness.

In terms of the teaching effectiveness of the flipped classroom, numerous studies across various disciplines have been conducted both domestically and internationally. Mandasari and Wahyudin (2021) aimed to describe the implementation of the flipped classroom learning model and analyze its impact on student satisfaction in a grammar class. They found that the flipped classroom was easy to implement, promoted self-directed learning, and improved students' grammar knowledge. Similarly, Laura-De La Cruz et al. (2022) explored the relationship between the flipped classroom and English language learning. Their results indicated a significant correlation between the flipped classroom model and improved English learning outcomes.

The flipped classroom has also become increasingly prevalent in mathematics education. Güler et al. (2023) highlighted its growing use, while Song (2020) proposed several strategies for its implementation, including a 5-D pedagogical framework, varied methods of teacher facilitation and student interaction, and the use of technology both in and outside the classroom. Findings from Song's study showed that these innovative strategies were generally effective in enhancing students' mathematics learning. In the field of healthcare education, nurse practitioner students who participated in a flipped learning course reported increased engagement with the content and improved confidence in applying knowledge and skills in clinical practice (Sullivan, 2022). Similarly, Barranquero-Herbosa et al. (2022) suggested that the use of the flipped classroom in nursing education improved student performance and received positive evaluations from both students and faculty.

Polat et al. (2022) investigated the relationship between flipped learning readiness, engagement, social anxiety, and academic achievement in an online flipped classroom involving 200 first-year university students in an information technology course. The study revealed that engagement was the most significant predictor of academic achievement. Likewise, Mashxura et al. (2023) found that using a flipped classroom in a computer graphics course enhanced student learning in an engaging way. Chang et al. (2022) proposed a teaching model that included the design of learning objectives, learning content, and group activities. This model supported the development of students' independent learning, logical thinking, problem-solving abilities, learning outcomes, and motivation. Wu (2022) explored the application and evaluation of the flipped classroom using micro-video lessons. The results showed that students expressed high satisfaction with this approach.

Empirical evidence showed that flipped classrooms have been successfully applied across various disciplines and have demonstrated positive teaching outcomes and student experiences. However, most studies have focused on student engagement and learning outcomes without offering detailed insights into the actual implementation processes.

The automotive industry is undergoing its most profound transformation in a century, with ICV considered a key area of future competition. To adapt to societal developments, an increasing number of educational institutions have begun offering courses on ICV technology (Wang et al., 2023). Tian et al. (2022) proposed a structure for both the theoretical and practical components of an introductory ICV technology course. Based on the Outcome-Based Education (OBE) model, Pi (2021) developed teaching objectives and a syllabus for the course, introduced a project-guided instructional approach, and provided detailed content and time allocations for these projects. However, these studies were primarily based on traditional teaching models. As emerging technologies continue to evolve, the limitations of traditional approaches have become more apparent, they no longer meet the needs of modern teaching and fail to provide effective models for course implementation.

2.1. Theoretical Framework

Teaching theory is a crucial component of education, providing the foundation and framework for effective instructional implementation. Therefore, constructivist learning theory was adopted in this study. Constructivist learning theory emphasizes a student-centered approach. It requires students to shift from being passive recipients of external stimuli and objects of knowledge indoctrination to becoming active processors of information and constructors of meaning. Likewise, it calls for teachers to transition from knowledge transmitters to facilitators and supporters of students' active learning and meaning-making (He, 1997).

In this study, the theory underscores the use of diverse information resources to support learning. Through the flipped classroom model, various teaching media and materials were provided to promote students' independent learning and collaborative inquiry. Emphasis was placed on a student-centered approach that fully leveraged students’ initiative in the learning process, thereby exploring the effectiveness of the instructional process.

This approach enabled students to better understand and solve real-world problems by receiving more feedback based on their own actions. Constructivist principles guided the

design of the teaching pathway, including: analysis of teaching objectives, creation of meaningful learning contexts, development of information resources, design of self-directed learning activities, creation of collaborative learning environments, evaluation of learning outcomes, and development of reinforcement exercises.

3. Methodology

3.1. Research Design

This study employed a qualitative descriptive research design. The participants primarily included teachers from Shaanxi Polytechnic Institute and students majoring in Automotive Intelligent Technology. Participant selection followed an objective and non-discriminatory process to ensure fairness and representativeness.

3.2. Participants of the Study

Interview participants were selected through purposive sampling based on specific criteria. In line with the principles of purposive sampling (Patton, 2002), the selection ensured the information richness and typicality of the sample. Teachers were required to have more than three years of teaching experience and to have implemented flipped classrooms in their actual teaching practice. Among the eight teachers involved in flipped classroom instruction within the program, only five had more than three years of teaching experience and thus qualified for participation. These five teachers were interviewed. On the other hand, students were selected from the 2301 class of the Automotive Intelligence program, in which the ICV Technology course was offered. As only one major offered the Vehicle Technology course, and that major included only one class with 28 students, the study focused on this particular group. To account for potential student absences during the course, 10 students who had participated throughout the entire course were selected. Although the sample size was limited by the program's current structure, theoretical saturation was achieved.

Participants who did not meet the required criteria were excluded from the study. Teachers were excluded if they had less than three years of teaching experience or had not implemented flipped classrooms in their teaching. Similarly, students were excluded if they were not part of the Automotive Intelligence Class 2301 or had not completed the ICV Technology course.

3.3. Instrumentation and Data Gathering Process

Semi-structured one-on-one interviews were used to collect data. The interviews were divided into two parts: student interviews and faculty interviews. The teacher interview outline consisted of seven topics, while the student interview outline covered eight. However, during the actual interviews, the interviewer retained the flexibility to adjust the questions based on the flow and content of the conversation.

To ensure validity and reliability, the interview outlines were submitted to the faculty office for ethical review and tool validation before the interviews were conducted. Based on the feedback received, the outlines were revised to align more closely with the research objectives. Prior to conducting the interviews, the interview protocols underwent ethical review and tool validation. The researchers also obtained permission from the teaching department of Shaanxi Polytechnic Institute and formal consent to conduct one-on-one interviews with teachers and students. The interview process was designed to ensure scientific rigor, including measures to maintain data reliability, participant privacy, and information security.

Before each interview, the researcher provided the participant with a detailed explanation of the study's purpose, the interview process, how the data would be used, and obtained written informed consent. Participants were informed that their responses would be anonymized and that they could withdraw from the study at any time. Interviews were scheduled according to the participants' availability and conducted in quiet, private settings to minimize distractions.

During the interviews, a semi-structured format was used to allow flexibility while maintaining focus on the core research questions. With participants' consent, data recording equipment was used to ensure the completeness and accuracy of the information collected. All interview data were anonymized and did not include identifiable details such as workplace names, class identifiers, or contact information. Audio and textual data were securely stored on an encrypted hard drive accessible only to the research team.

After data collection, the interview transcripts were coded and categorized using thematic analysis to extract key themes. The credibility of the findings was enhanced through cross-validation of data collected from both faculty and student participants.

3.4. Data Analysis

To ensure the rigor and credibility of the qualitative analysis, this study employed thematic analysis following Braun and Clarke's (2006) six-phase approach. The analysis was guided by the research objectives and aimed to identify recurring patterns across interviews with both teachers and students. A thematic table was constructed to summarize themes, sub-themes, frequencies, and interviewee codes, systematically organizing the data.

Familiarization with the data. All interview recordings were transcribed verbatim to preserve the nuances of participants' expressions. The researchers immersed themselves in the data by reading and re-reading the transcripts. Initial observations were noted, particularly focusing on recurring issues such as student readiness, technological resources, and student engagement.

Generating initial codes. The transcripts were systematically coded using a combination of deductive (based on research questions) and inductive (emerging from data) approaches. Codes were assigned to meaningful data segments and grouped under preliminary categories. For instance, codes related to "student readiness" and "pre-class assignments" were categorized under Prior Knowledge and Preparation, while those referencing "platform stability" and "internet connectivity" were grouped under Availability of Technological Resources.

Searching for themes. The initial codes were reviewed and organized into broader themes and sub-themes aligned with the research objectives. This thematic clustering was informed by code frequency and the diversity of interviewees contributing to each theme. For example, Prior Knowledge and Preparation reflected the influence of student readiness and the importance of pre-class tasks, while Availability of Technological Resources encompassed both platform stability and access to technology. Student Engagement and Participation captured the impact of motivation and self-discipline on learning in a flipped classroom setting.

Reviewing and refining themes. Preliminary themes and sub-themes were reviewed to ensure internal consistency and distinction from each other. Codes were cross-checked with the original transcripts to verify accurate representation. For example, Prior Knowledge and Preparation was refined to emphasize both student readiness and the necessity of pre-class assessments. Likewise, Availability of Technological Resources was clarified to include both access and performance issues.

Defining and naming themes. Each theme was clearly defined to reflect its underlying meaning and relevance to the research questions. Definitions included associated sub-themes, frequency of occurrence, and the diversity of perspectives from teachers and students. For example, Prior Knowledge and Preparation highlighted the importance of student readiness and the role of pre-class work in promoting engagement, while Availability of Technological Resources emphasized platform reliability and access to digital tools. Theme names were kept concise and descriptive to ensure clarity and consistency.

Writing the report and integrating findings. Once the thematic structure was finalized, the researchers transitioned to report writing. The findings were presented according to the identified themes and sub-themes and supported by rich qualitative evidence, including direct quotes from participants. Each theme was discussed in the context of its impact on flipped classroom teaching and learning in the ICV technology course, providing a comprehensive narrative of how these factors shaped classroom dynamics.

3.5. Research Ethics

To ensure ethical research practices, several measures were implemented to protect participants' privacy, confidentiality, and voluntary participation, while minimizing potential risks. All data collection procedures were designed to safeguard privacy by ensuring that no personal or identifiable information was recorded. Instead, unique codes were assigned to participants to maintain anonymity, and all data were securely stored with restricted access limited to authorized researchers.

A non-disclosure agreement was enforced to ensure confidentiality, prohibiting the sharing or discussion of participant-related data outside the research context. All researchers and personnel involved in data handling signed this agreement to protect participants' identities and the sensitive information they provided. Additionally, no personal data unrelated to the study were collected, and all datasets were fully de-identified.

Participation in the study was entirely voluntary. Participants had the right to withdraw at any time without explanation or consequence. Before each interview, participants were provided with an informed consent form. Only those who gave written consent were included in the study. Participants were also offered the option to receive a summary of the study's findings, promoting transparency and keeping them informed of research outcomes.

To minimize potential risks, the study underwent strict ethical scrutiny to ensure that the interview content did not include sensitive topics likely to cause distress. Participants' emotional well-being was closely monitored throughout, and interviews were paused or terminated if necessary. The study did not involve any invasive procedures, and every effort was made to avoid long-term physical, emotional, or psychological harm.

Furthermore, participants were not required to spend money or use their personal resources to participate. No financial contributions were expected, ensuring that participation remained entirely voluntary and free from burden. The participant selection process was objective and non-discriminatory, promoting fairness and inclusion while upholding the highest ethical standards to protect participants' rights and well-being.

4. Findings

This section presents the findings from the analysis of qualitative data collected through interviews with teachers and students involved in flipped classroom teaching for the ICV Technology course. The thematic analysis revealed multiple factors influencing the effectiveness of the flipped classroom approach, as well as its perceived impact on learning outcomes.

4.1. Factors Affecting Flipped Classroom Teaching

Teachers and students mentioned that flipped classroom teaching was influenced by multiple factors. Several themes emerged in the analysis of the interview results, with the identified themes being prior knowledge and preparation, availability of technological resources, student engagement and participation, teacher's role in monitoring learning, importance of student feedback, flexibility in teaching strategies. The supporting comments in these themes and data are summarized as follows:

Prior Knowledge and Preparation. Teachers emphasized that students' level of preparation directly influences the effectiveness of the flipped classroom. Students with a solid foundation engage more actively in discussions. As one teacher noted,

> *"The richer the students' knowledge accumulation before class, the more interested they will be during class, and the easier it will be to grasp key points when listening to lectures" (T3).*

On the contrary, if students were not adequately prepared before class, classroom interaction will be significantly limited. A teacher emphasized that,

> *"students with insufficient prior knowledge or inadequate preparation may feel lost in the classroom, struggle to keep up with the pace, and thus reduce the effectiveness of flipped classrooms" (T5).*

Availability of Technological Resources. Both teachers and students acknowledged that technology plays a crucial role in the flipped classroom. Three teachers stated,

> *"Technical resources should be combined with teaching resources" (T2).*
> *"The more technical support there is, the more convenient it is for students to use software, which can provide a basic guarantee for their learning" (T3).*
> *"Adequate technical resources can ensure that students can smoothly obtain pre-class learning materials and engage in self-directed learning" (T5).*

While platforms like Wisdom Tree provided structure, unstable connectivity remained a challenge. A student shared, *"The Wisdom Tree platform is easy to use, but when the internet is slow, I tend to lose motivation" (S7).*

Student Engagement and Participation. Students who were self-disciplined benefit more from the flipped classroom, whereas others struggle. One teacher explained,

> *"Students who lack self-regulation find it difficult to complete pre-class activities, which affects their in-class performance" (T5).*

On the contrary, students with strong self-discipline were more likely to adapt to the flipped classroom model. They were able to actively arrange their learning time, improve classroom participation and learning outcomes. A student stated in an interview that,

> *"Flipped classrooms provide more opportunities for self-directed learning and self-control, allowing students to understand classroom content at their own pace and improve classroom learning" (S1).*

Teacher's Role in Monitoring Learning. Teachers utilized learning analytics to track student engagement and adjust their strategies accordingly. Two teachers said,

> *"I will check students' learning status in a timely manner, and if they are not doing well, I will send reminder notifications to students on the system" (T3).*

"I will set deadlines and urge students to complete on time"(T5).

Teachers provided personalized guidance and support by analyzing students' learning. A teacher proposed,

"We will provide one-on-one guidance on some issues through online discussions. Most people have similar problems and will solve them in class" (T1).

Importance of Student Feedback. Student feedback was a vital factor in refining the flipped classroom approach. Three teachers shared,

"If students find certain topics difficult, we re-explain them using different materials in the next session" (T2).

"*If students are interested in classroom discussions, I will increase the difficulty and depth of classroom discussions in subsequent courses" (T3).*

"I will add some new technology sharing based on students' performance" (T1).

Flexibility in Teaching Strategies. Teachers highlighted the importance of varied learning materials to accommodate different learning styles. As teachers mentioned,

"We provide a combination of videos, readings, and quizzes to suit students' preferences" (T4).

"Differentiated teaching methods should be emphasized to meet the needs of different students and adapt to different learning rhythms" (T5).

Students also agreed that flexible teaching strategies play an important role in flipped classrooms. Two students stated,

"Flipped classroom provides a variety of learning resources, such as videos, chapter quizzes, and basic questions from teachers" (S1).

"The flipped classroom mode allows us to engage in personalized learning, independently selecting learning content and pace based on our own interests and goals" (S5).

4.2. Effectiveness of Flipped Classroom for the ICV Technology Course

Although students and teachers had a relatively positive attitude towards flipped classrooms, they still faced some challenges. Five themes appeared in the thematic analysis.

Enhanced Understanding of ICV Concepts. Students appreciated that flipped classrooms allowed for deeper exploration of ICV technology. One student shared,

> *"The flipped classroom connects classroom teaching with the real-time updates in automotive technology, which helps me understand industry trends faster" (S4).*

Another student added,

> *"Provide more opportunities to discuss intelligent connected vehicle technology with teachers, explore updated new technologies in real time, and deepen understanding and mastery of professional fields" (S1).*

Increased Student Motivation. Many students found flipped classrooms more engaging than traditional methods. Two students said,

> *"Compared to traditional lectures, flipped classes give me more control over my learning, making it more interesting and motivating" (S2).*
>
> "*Flipped classroom can stimulate our understanding of new knowledge, make us more eager for knowledge, and make the classroom more interesting and lively "(S4).*

Some students also believe that pre-class learning in flipped classrooms makes them more confident and focused in the classroom. A classmate said in an interview,

> "*Through flipped classroom pre-class material learning, I am able to participate more confidently and actively in the teacher's questions during classroom activities*" *(S5).*

Improved Classroom Interaction. Students noted that flipped classrooms improved interaction through Q&A sessions and group discussions. Two students mentioned,

> *"The interactive modules, like Q&A and brainstorming, make the class more engaging and encourage me to participate more actively" (S5).*
>
> *"Online questioning allows us to communicate and share our learning experiences with teachers and classmates at any time, encouraging us to actively participate" (S10).*

Adaptability to Different Learning Styles. The flexibility of the flipped classroom allowed students to learn at their own pace. One student explained,

> *"I like how I can watch videos multiple times to better understand concepts, especially for technical topics like ICV technology" (S6).*

However, students with low self-regulation abilities also face challenges. A classmate said,

> *"For some students who rely too much on teacher guidance and have poor self-learning abilities, flipped classrooms may be difficult" (S1).*

Effectiveness of Pre-Class Materials. Video-based learning emerged as the most preferred format for pre-class materials. Two students shared,

> *"Watching recorded videos by our own teachers makes learning more engaging and easier to understand" (S1).*
> "*Through some videos, we can deepen our understanding of intelligent connected vehicle technology" (S4).*

Testing and interaction can better demonstrate the effectiveness of pre-class material learning. A classmate said,

> *"Through the test, one can understand their mastery of the knowledge points" (S3).*

5. Discussion

In recent years, the flipped classroom has become a widely researched and increasingly adopted teaching model in higher education, particularly in technical fields such as ICV technology (Le, 2024). This study focused on identifying the key factors that influence the success of flipped classroom implementation and evaluating its effectiveness in enhancing student engagement and learning outcomes within an ICV technology course. By exploring both instructor and student perspectives, the research provides insights into how flipped classrooms can be optimized to meet the specific demands of this complex, technology-driven subject. The findings contribute to a deeper understanding of how flexible, student-centered teaching approaches can be practically applied in engineering education to promote active learning and improve academic performance.

The findings of this study show that students' prior knowledge and learning preparation are key factors for the success of flipped classroom teaching. This highlights the foundational role that readiness plays in active learning environments. In flipped classrooms, where in-class time is largely dedicated to application, problem-solving, and higher-order thinking, students who come prepared with a solid understanding of the material are better positioned to engage meaningfully. This readiness allows them to participate confidently in discussions, collaborate

effectively, and maximize the benefits of interactive activities. These findings are consistent with the literature (Clark & Post, 2021). Well-prepared students demonstrate greater confidence in class, and their classroom performance, participation, and learning interest are higher. Multiple studies indicate that the flipped classroom is a practical learning approach that enhances student engagement, performance, and learning outcomes (Aidoo et al., 2022; Torres-Martín et al., 2022).

Teachers assessed students' prior knowledge before the course began to ensure smooth preparation and to maximize the effectiveness of flipped classroom teaching. Watching and reviewing videos before class deepened students' understanding of key knowledge points. The adoption of flexible teaching strategies allowed students to learn at their own pace anytime and anywhere, consistent with previous research highlighting the flexibility of flipped classrooms (Dikilitas & Fructuoso, 2023; Förster et al., 2021). Students who exhibited higher self-discipline demonstrated greater initiative and motivation (Laswadi et al., 2023) and were able to grasp knowledge better in a flipped classroom setting.

Consistent with relevant literature, self-discipline is crucial as it directly affects students' ability to learn independently (Mengyan & Haitao, 2024). The results also showed that student feedback is an important factor influencing flipped classrooms, with teachers adjusting and improving teaching strategies accordingly. This student-centered approach aligns well with constructivist theory, supporting the cultivation of academic inquiry and innovation ability (Jiang et al., 2020). This finding is further supported by literature emphasizing the importance of engaging students in ongoing education to promote active and reflective learning for purposeful improvement (Howel, 2021).

While flipped classrooms offer many pedagogical advantages, their dependence on technology presents significant challenges. The effectiveness of flipped learning relies on students having reliable access to digital resources such as stable internet connections and appropriate devices. When technical resources are insufficient or unstable, students face interruptions in accessing pre-class materials, which can hinder their preparation and engagement. Similarly, teachers may struggle to deliver content or track student progress effectively. This technological barrier can exacerbate educational inequities, disproportionately affecting students from under-resourced backgrounds. This finding aligns with previous research indicating that inadequate infrastructure, such as poor internet

connectivity and lack of ICT devices, limits the use of flipped classroom methods (Aidoo et al., 2022).

The results also revealed the effectiveness of the flipped classroom in teaching ICV technology. Both teachers and students reported that flipped classrooms enhance learning and understanding of new connected technologies. This indicates that the flipped classroom model positively impacts learning and comprehension of emerging connected technologies in the ICV field. By shifting foundational learning to pre-class activities and reserving class time for application and problem-solving, students are better prepared to grasp complex technical concepts. The interactive elements of the flipped classroom, such as discussions, real-time Q&A, and case-based learning, provide opportunities for students to engage with both theoretical and practical aspects of new technologies, deepening their understanding. This model offers a way to rethink learning and educational processes (Khayat et al., 2021). Huang et al. (2022) and Birgili et al. (2021) found that most students had positive perceptions of the flipped classroom regarding engagement, usefulness, effectiveness, expectations, and satisfaction, and would recommend courses taught using this approach.

The results of the study also showed that flipped classroom can improve the classroom experience and increase students' motivation and interactivity in learning. The findings suggest that the flipped classroom model not only enhances academic performance but also positively affects the overall classroom experience by fostering a more interactive and engaging environment. By shifting passive learning activities (e.g., watching lectures) to pre-class tasks, the model frees up valuable in-class time for active learning, such as discussions, group work, and problem-solving. This increased interactivity allows students to engage more deeply with the material and with each other, thereby boosting motivation and participation levels. When students feel more connected to the learning process and their peers, it creates a positive feedback loop of enthusiasm and engagement. These findings confirm previous research showing that flipped courses create a user-friendly, collaborative learning environment with enhanced student achievement, autonomy, and motivation (Challob, 2021). In addition, the findings suggest that flipped classrooms can effectively adapt to different learning styles and create a dynamic learning environment where students learn fundamentals at home and engage in active learning activities in the classroom (Gong et al., 2024).

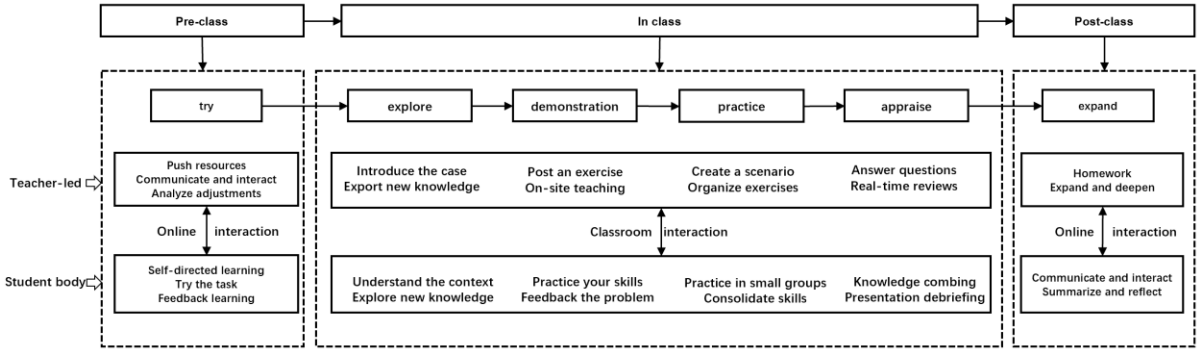
By analyzing the influencing factors and effectiveness of flipped classrooms, it was found that flipped classrooms can build a student-centered learning model and improve

learning outcomes in intelligent networked vehicle technology courses. This is consistent with the "student-centered" educational concept embodied in the flipped classroom application model described in the literature (Dong, 2014). As noted in prior studies, flipped classrooms as a teaching method significantly help students improve their learning motivation and understanding of knowledge, while teachers demonstrate a positive attitude toward student-centered learning (Utami et al., 2024).

Therefore, through interviews with students and teachers, combined with the characteristics of the ICV technology course and utilizing the Wisdom Tree platform, a dual-subject, three-stage teaching path was constructed (as shown in figure 1). "Dual-subject" refers to the teacher-led and student-led components; "three stages" refers to dividing the teaching process into three chronological stages: pre-class, in-class, and post-class.

Figure 1

"Dual Subject Three Stage" teaching path of intelligent connected vehicle technology course



Pre-class. Self-directed learning before class allowed students to develop a deeper understanding of the problems they would encounter during class and improved their participation. As a student-centered approach, the flipped classroom enhanced the quality of face-to-face time spent in the classroom and provided opportunities for active learning setups (Awidi & Paynter, 2018; Murillo-Zamorano et al., 2019). Teachers assigned materials such as learning videos on ultrasonic sensors, learning objectives, reference materials, and pre-class tests. Students completed these pre-class tasks in a timely manner. During online self-directed learning, teachers and students interacted in real time to answer questions. By analyzing students' completion of pre-class tasks and test results, teachers adjusted the teaching content accordingly.

In class. The class was mainly divided into four parts: case exploration, teacher demonstration, student practice, and mutual appraisal.

Case exploration: The teacher presented failure cases of the ultrasonic sensor, introduced new knowledge, explained theoretical concepts, addressed difficulties based on students' pre-class feedback, and emphasized key content related to the ultrasonic sensor. Students analyzed failure cases, identified gaps, and continuously reinforced their theoretical knowledge.

Teacher demonstration: The teacher demonstrated the detection, installation, and assembly of the ultrasonic sensor. Students carefully observed and recorded the procedure. If students encountered knowledge gaps, they watched the related videos repeatedly online.

Student practice: The teacher divided students into groups, each group assigned fault points on different ultrasonic sensors and given practice tasks. Students practiced in groups with assigned roles, engaged in group discussions, designed maintenance plans, and carried out the tasks while recording their progress. The teacher promptly addressed any questions that arose during the practice.

Mutual appraisal: Each group presented their ultrasonic sensor maintenance plan along with installation and commissioning results. The teacher conducted evaluations, along with inter-group peer evaluations and intra-group self-evaluations. The teacher then summarized and organized the feedback.

After-class. Teachers assigned homework and extension tasks, which students completed on time. If students had questions, teachers interacted with them online promptly to provide support.

In this model, teachers transitioned from traditional knowledge transmitters to knowledge guides, while students transformed from passive recipients to active explorers through a dual-subject approach. This facilitated the coordinated development of social construction and individual internalization. During the classroom teaching phase, the four-step closed-loop of "Case exploration–Teacher demonstration–Student practice–Mutual appraisal" was designed to operationalize Vygotsky's scaffolding theory (Zhu, 2011), especially through real project cases of ICV, allowing empirical support for the theory of the zone of proximal development in engineering education.

6. Conclusion

This study identified the benefits and challenges of applying flipped classrooms in the ICV technology curriculum. It showed that the implementation of the flipped classroom in this course achieved positive learning outcomes, providing strong support for students' learning. The findings further offer a student-centered, participatory teaching method for educators in ICV technology and provide a conceptual framework for teaching reform in ICV technology courses. However, the practical effectiveness and areas for optimization of this teaching approach need to be further validated and improved through subsequent empirical research.

On the other hand, since this study is limited to the application in automotive intelligence, future research should consider the diversity of applications across other majors and institutions that offer this course. To further evaluate the effectiveness of the flipped classroom in this context, quantitative research should be conducted to address issues across different classes. Future studies could incorporate quasi-experimental designs to compare the effectiveness of traditional teaching with the "dual-subject, three-stage" model across various majors, as well as track and evaluate the long-term sustainability of learning outcomes.

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Institutional Review Board Statement

This study was conducted in accordance with the ethical guidelines set by the University of Baguio Research Ethics Review Committee.

AI Declaration

The authors utilized ChatGPT and QuillBot in the preparation of this work to improve readability and language. Consensus AI and Elicit AI were also used for purposes of literature review, while Scribbr was used for reference formatting. The authors reviewed and edited all content produced through the use of these tools, for which they fully accept responsibility in the final publication.

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