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Research article

The effectiveness of blended learning on students' academic achievement, self-study skills and learning attitudes: A quasi-experiment study in teaching the conventions for coordinates in the plane

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ABSTRACT

Individuals attempting to study remotely during the COVID-19 lockdown will find that blended learning is a helpful solution and results in a significant increase in learning engagement. The best benefits for teachers and students are obtained by maximizing the advantages of each teaching method and by combining the advantages of online and face-to-face instruction. The study aims to investigate the effectiveness of the flex model of blended learning in teaching the mathematics subtopic of coordinates in the plane through the improvement of students' academic achievement, self-study skills and learning attitudes. A quasi-experiment was conducted to compare the academic achievement, self-study skills and learning attitudes of 46 students in the control class who used traditional methods to those of 44 students in the experimental group who used the blended learning model. The pre-and post-test results, observations, and student opinion survey were used to compile data, which were then analyzed quantitatively (with SPSS) and qualitatively. The study confirmed that blended learning positively impacts students' academic achievement in the experimental class compared with the control class (Sig (2-tailed) = 0.001 and SMD = 0.6717), as demonstrated by the outcomes of the independent t-test analysis of the two groups in the post-test phase. In addition, observations and student opinion survey results also indicated that blended learning increased student interactions with teachers and improved students' academic achievement, self-study abilities and learning attitudes. Due to time constraints, not all the students who participated in the experiment could make progress. On the other hand, the study's relatively small sample size gave the impression that the results were only partially representative of the population. As a result, additional studies focusing on improving the effectiveness of teaching and learning within different blended learning models, broadening the scope of research on the influence of blended learning in other subjects, or increasing the sample size can all be considered.

1. Introduction

In the context of the rapidly developing scientific and technical revolution, the education and training sector has actively implemented tasks and solutions to enhance support management, teaching, learning, assessment, scientific research, and the application of information and communication technology (ICT) (Acosta et al., 2018; Baris, 2015; Bray and Tangney, 2017; Diabat and Aljallad, 2020).

In order to ensure the progress and effectiveness of students' learning within the context of the COVID-19 pandemic, the education and training industry has promoted the combination of remote "face-to-face" teaching via television and online teaching via the Internet (Attard and Holmes, 2020; Ho et al., 2020; Hori and Fujii, 2021; Mukuka et al., 2021; Pham et al., 2021; Stahl, 2021). The industries likewise promoted standardized assessment and recognition of academic achievement using online images. Accordingly, some commonly used applications, such as Microsoft Teams, Google Meet, Zoom (Ho et al., 2020), Facebook (Barros et al., 2017), and Zalo (a social networking application developed and widely used in Vietnam), allow users to combine video discussion and screen sharing tools, allowing teachers to interact and manage the learning progress of multiple students simultaneously (Sun et al., 2020).

A combination of intuition and abstract thinking should be involved in teaching geometry. The Cartesian coordinate system in the plane is an important topic of the high school mathematics program and serves as a

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basis for learning geometry in later grades. However, students often have difficulty learning this topic due to the absence of visual aids. A disadvantage of the traditional teaching approach is that it reduces the opportunities for solving problems through applications and acquiring knowledge. However, combining lectures with images, videos, and other learning content in the classroom will make these lessons more effective for teachers. Additionally, students will feel more engaged and active in acquiring knowledge, teaching and learning will improve, and applying geometric concepts will be easier.

Since these learning environments have similarities, the combined learning method with traditional and online learning spaces works well for mathematics education. Some in-depth studies have implemented blended learning for teaching mathematics at various skill levels (Alammary, 2019). Studies have shown that personalized learning helps promote students' motivation, enhances the efficacy of math learning, and enables learning to be tailored to students' interests. As a result, more research must be done to study blended learning as an effective learning trend for the future (Baris, 2015). Various studies have investigated the application of blended learning to teaching practices in mathematics education. Research by Kashefi et al. (2012) aimed to support K-12 students' mathematical thinking in learning two-variable functions through blended learning. Balentyne and Varga (2017) investigated the relationship between students' achievement and their attitudes in a self-paced blended mathematics course with 23 eighth-grade students in Algebra I and Geometry. In addition, Lin et al. (2017) investigated the effect of blended learning on seventh-grade students' academic achievement in a mathematics course on numbers and number lines. Liang et al. (2018) designed lessons with a calculus e-learning system for first-year university students with diverse mathematical backgrounds. The study by Stahl (2021) proposed a model for such learning; it illustrated using existing dynamic-geometry technology to translate the study of Euclidean geometry into collaborative learning via student pods. Pambudi (2022) studied how to increase elementary students' motivation and learning achievements in geometry.

In the meantime, several studies focused on the perceptions and experiences of blended learning among students and teachers. Rifa'i and Sugiman (2018) measured seventh-grade students' perceptions of their learning experience in the mobile blended learning environment. Weinhandl et al. (2018) focused on the technology-supported Flipped Classroom Approach (FCA) in mathematics education and how this teaching and learning can be implemented in secondary schools. Research by Avineri et al. (2018) applied technology to the professional development of mathematics teachers. Attard and Holmes (2020) researched 10 case studies in mathematics classrooms from preschool to the 12th year in nine Australian schools to investigate technology-mediated practices from teachers' and students' perspectives. The paper of Mukuka et al. (2021) reported the findings of descriptive survey research that explored secondary school students' experiences with remote learning in mathematics during the COVID-19 school closures, with a sample of 367 students ages 13 to 21. Therefore, it is clear that blended learning has been adopted in various mathematics topics at different levels.

Regarding mathematics education in Vietnam, online learning is becoming increasingly popular since the outbreak of COVID-19. As Sarkar et al. (2022) mentioned, the solutions to real-life problems are challenging to find out in the exact form as the dimensions of the problems are significant (Sarkar et al., 2022). Therefore, educators must investigate different aspects of applying blended learning in mathematics education, such as its characteristics, benefits and challenges, especially its effectiveness and applicability in teaching mathematics in Vietnam. However, the number of studies on the application of blended learning in teaching mathematics in the Vietnam education context is relatively small, and no research has been done on how effective the flex model of blended learning is for teaching the topic of coordinates in the plane. Therefore, this study is conducted to determine whether using blended learning to teach Vietnamese 10th-grade students about coordinates in the plane during COVID-19 lockdowns effectively raises students' academic achievement, self-study skills and learning attitudes.

2. Literature review

2.1. Definition and characteristics

Blended learning is a student-centered learning method (Vasileva-Stojanovska, 2015) that combines traditional face-to-face classrooms (synchronous learning activities) with e-learning activities (asynchronous learning activities) (Attard and Holmes, 2020; Keržič et al., 2019). Gambari et al. (2017) emphasized the role of the e-learning factor, according to Adiguzel et al. (2020). According to Owston and York (2018) and Lazar et al. (2020), the ratio between face-to-face and online learning in blended learning varies, but the online learning factor should be between 33% and 50%, and even as high as 80% (Lazar et al., 2020; Owston and York, 2018). In blended learning, e-learning tools are used in lessons, training sessions (Adiguzel et al., 2020), presentations, progress learning, and online discussion groups (Alammary, 2019).

According to Lazar et al. (2020), blended learning results from digital technology and digital educational tools. Online tools such as apps, books, and computers can be used as lesson plans, lectures, textbooks, assignments, software, quizzes, tests, resources, audio and video, digital, and social networking platforms such as Twitter, YouTube, and Facebook (Watling, 2012). Meanwhile, Lazar et al. (2020) used the concept of "digital learning tool" to refer to digital sources used in blended learning, including:

(1) High-tech digital learning tools: these include software to support student learning, such as interactive boards, scientific software, applications, digital teaching software, digital textbooks, and mobile devices (smartphone or tablet).
(2) Traditional digital tools: these include digital video support, aerial video projectors, interactive materials, digital assemblies containing interactive resources, and reference content such as lecture notes and dictionaries (Lazar et al., 2020).

From the perspective of mathematical education, Kashefi et al. (2017) state that the components of blended learning include author, teacher, student, method, technology, and math. In it, the author is the one who creates the course and defines the role of each component. Blended learning emphasizes strengthening the connections among students, teachers, and students; other stakeholders are also incorporated into the learning process. Authors can use various technologies with pedagogy to develop tasks and complete math assessments for their students (Kashefi et al., 2017).

Blended learning consists of five components, of which two are face-to-face and three are online (Alammary, 2019). These units include:

(1) Face-to-face instructor-led: students participate in a class where the teacher presents the learning content, and there is little interaction, experiential learning, or practice.
(2) Face-to-face collaboration: encourages students to participate in learning activities together in the classroom.
(3) Online instructor-led: the teaching process is accomplished online with the teacher's assessment of the learning progress and interactions throughout the learning process.
(4) Online collaboration: encourages students to participate in learning activities online.
(5) Online self-paced: allows students to study at their own pace, with flexible time and space.

2.2. Models

Many studies have produced different models of blended learning. A review by Alammary (2019) has shown five models classified according to where content is communicated and where practical activities take place (face-to-face or online), including the flipped, mixed, flex, supplemental, and online-practicing models (Alammary, 2019).

(1) Flipped model: Students are guided to access prepared materials before starting lessons. Preparation takes place outside of school hours via an online format and is then leveraged to maximize teacher and student opportunities for interaction, collaboration, debugging, and manipulation during face-to-face learning (Alammary, 2019; Weinhandl et al., 2018).
(2) Mixed model: transmission of learning content and practice tasks conducted face-to-face and online (Alammary, 2019).
(3) Flex model: learning content and practical tasks are transmitted through online teaching; however, students will participate in face-to-face sessions to check progress and receive feedback on the learning process (Alammary, 2019). Hauswirth and Adamoli (2017) have organized online teaching with various tasks such as watching videos, researching books, participating in online discussions, or solving exercises. Teachers enable students to learn at their own pace, and students see one another regularly and in person for classroom instruction (Hauswirth and Adamoli, 2017).
(4) Supplemental model: knowledge and practice learning is improved through face-to-face learning; however, online activities are added to enhance student engagement (Alammary, 2019).
(5) Online-practicing model: this model allows students to practice, solve problems online, and obtain instant feedback through the online learning platform (Alammary, 2019).

Furthermore, Tesch (2016) also offered six blended learning models: face-to-face driver, station rotation, online lab, flex, self-blend, and online driver. While improving students' learning efficiency, teachers use various technology devices to guide and facilitate classroom learning processes in the face-to-face model (Tesch, 2016; as cited in Alsalhi et al., 2021). It is flexible and meets the needs of elementary and middle school students by providing teachers with additional resources as students' needs change (Barros et al., 2017). The online lab school model offers students the additional benefit of online study time in dedicated computer labs. Meanwhile, the self-blend model allows learners to participate in the courses. There is a significant gap between online and formal learning because of the student's unique needs (Alsalhi et al., 2021); similar to the supplemental model; the online-driver model has characteristics similar to the online-practicing model.

These learning models have been applied in many blended learning studies, such as Cronhjort et al. (2018) and Attard and Holmes (2020) with the flipped model and Barros et al. (2017) with the rotation model. It is necessary to select an appropriate blended teaching model that meets the needs of each educational facility based on various factors, such as facilities, financial capabilities of the school, subject and curriculum, and more, depending on each school's capacity. This study considers the current conditions and research needs and, therefore, chooses the flex model as the starting point of the design for the experimental lectures.

2.3. Implementation and assessment

Keržič et al. (2019) proposed that effective blended learning encompasses a complex teaching method that supports face-to-face teaching but additionally supports students' work on projects, contributing to the learning process, and engaging in other activities. Students need constant supervision in an online classroom (Keržič et al., 2019). According to Poon (2013), Zhang and Zhu (2017), and Keržič et al. (2019), these factors can be divided into three groups:

(1) Student factors, including available information, technology knowledge/experience (Alsalhi et al., 2021), confidence, self-discipline (Alsalhi et al., 2021), learning style (Miyaji and Fukui, 2020), and responsibility for learning progress (Alammary, 2019; Poon, 2013; Zhang and Zhu, 2017).
(2) Teacher factors, including personality, ICT competence, teaching style, knowledge, facilities, feedback and course structure, online teaching, information quality, and communication quality (Alammary, 2019; Poon, 2013; Zhang and Zhu, 2017).
(3) Technology adoption and technical support, including ease of use, access, user-friendly interfaces, and technical support (Alammary, 2019).

Online learning materials support face-to-face teaching by adding further reading to finish the process. Following that is a self-assessment of the online learning material's concepts and content. Additionally, teachers give students feedback on assignments that involve long-term projects and have the students assess the quality of the work (Kashefi et al., 2012; Umek et al., 2015). Barros et al. (2017) and Keržič et al. (2019) stated that these assessment results offer students the information they need to acquire and feedback on how well they have learned. Also, teachers can see the extent to which the lesson is understood and the students' learning requirements must be interpreted and monitored to observe their learning progression (Adiguzel et al., 2020; Barros et al., 2017; Keržič et al., 2019). Similarly, for mathematics education in particular, in research by Kashefi et al. (2012, 2017), the elements of blended learning instruction include classroom tasks, assessment, computer and web aid, and strategies. Rifa'i and Sugiman (2018) outlined mobile blended learning techniques, which utilize students' mobile devices to create educational tasks and various learning strategies in math instruction.

Landenfeld et al. (2018) discussed three assessment methods employing various question types: quick warm-up questions, summary exercises, and diagnostic and summative assessments. Questions of various types provide personalized feedback while reinforcing critical knowledge in the learning process (Landenfeld et al., 2018).

All other things being equal, Hoyos et al. (2018) and Attard and Holmes (2020) specified numerous variables when employing technology in teaching and learning mathematics. The first is providing how students can ask questions and receive technical support. The second is learning management systems (LMS) and modes of use (Diep et al., 2017). Third, the affordability of specialized math software such as Geogebra or Desmo and math videos should be tested for their ability to clarify mathematical concepts from multiple perspectives. Finally, there is a consideration of how technology enables a diversity of math content and the pace at which students progress in the learning process (Attard and Holmes, 2020; Hoyos et al., 2018). These factors have an impact on teachers and the teaching process (or students and the learning process) when the instrumentalization of learning resources from the Internet has been used to acquire knowledge or to teach staff (or students) the activities that accompany learning software (Hoyos et al., 2018).

Additional student involvement in the learning process, particularly in blended learning-oriented teaching, is influenced by various technological variables. These measures include: gaining student attention, maintaining engagement, and re-engaging students when disconnected or unable to participate (Jeffrey et al., 2014). Teachers can use decoys to capture students' attention by making them curious and sparking their interest in making meaningful connections. Additionally, they can accomplish this goal by showing students that they are an important part of the class and the subject by participating in class actively and on time. Engagement is maintained by clear and transparent assessment instructions, challenging tasks, and providing immediate and real-life feedback. Students must be identified and given attention when they are having difficulties in order for them to re-engage successfully in the learning process. Teachers must also monitor and identify struggling students as early as possible, have direct contact with them, and foster an environment of discussion where they can be supported (Jeffrey et al., 2014). Teachers and students who use blended learning should use electronic communication media, such as chat, e-mail, and discussion platforms, to enhance communication in mathematical learning. More importantly, group activities and group presentations help students to engage in communication. Students use inquiry methods when they pair up, work in small groups, utilize critical thinking to solve problems, and use student examples while learning (Kashefi et al., 2012).

The blended learning environment is also favorable for organizing active teaching approaches such as STEM education (ElSayary, 2021; Kandakatla et al., 2020; Landenfeld et al., 2018), problem-based teaching, project teaching (Yunus et al., 2021) and collaborative teaching (Kandakatla et al., 2020). In addition, many specialized models with characteristics suitable for blended learning in mathematics education have been studied. These include the Modular Object-Oriented Dynamic Learning Environment (MOODLE) research platform (Hoyos et al., 2018; Landenfeld et al., 2018; Lin et al., 2017; Psycharis et al., 2013), Massive Open Online Courses (MOOCs) (Avineri et al., 2018; Borba et al., 2016), e:t:p:M® project (Mundt and Hartmann, 2018), Personal Online Desk, viaMINT (Landenfeld et al., 2018), MyMathLab learning system (Chekour, 2018), machine learning techniques (Ho et al., 2020) as well as other math learning software on smartphones (Borba et al., 2016; Orlando and Attard, 2016; Rifa'i and Sugiman, 2018).

2.4. Advantages

Numerous studies emphasizing technology have been conducted on applying blended learning in general and teaching mathematics in particular. Studies on blended learning have shown positive results for teachers' and students' learning processes. Due to the characteristics of blended learning, this teaching approach can optimize the strengths of face-to-face and online teaching (Alsalhi et al., 2021; Hu et al., 2021; Kashefi et al., 2017; Kerzič et al., 2019). Unlike face-to-face teaching, online teaching relies on extensive LMS functions, allowing for efficient goal-setting, document organization, the facilitation of learning, participation in learning, and the assessment of academic achievement (Adiguzel et al., 2020; Sun, 2016). In addition, online learning facilitates teacher-student, teacher-teacher and teacher-student-family interactions (Alammary, 2019; Alsalhi et al., 2021; Attard and Holmes, 2020; Hoyos et al., 2018; Miyaji and Fukui, 2020; Sánchez-Gómez et al., 2019), and more personalized learning and assessment (Mundt et al., 2018; Rifa'i and Sugiman, 2018) without the hindrance of space or time (Zhang and Zhu, 2017). Most studies show that blended learning creates a flexible learning environment that allows students to repeat lessons at the right time and place (Zhang and Zhu, 2017) by easily accessing and selecting learning content (Sánchez-Gómez et al., 2019; Uz and Kundun, 2018).

In addition, many studies have shown that blended learning can positively affect students' learning attitudes (Alsalhi et al., 2019; Balentyne; Varga, Gambari et al., 2017; Rifa'i and Sugiman, 2018; Zhang and Zhu, 2017), such as creating learning motivation, improving flexibility, self-confidence (Alammary, 2019; Alsalhi et al., 2021; Attard and Holmes, 2020; Lin et al., 2017; Mumtaz et al., 2017; Uz and Kundun, 2018), the ability to work in groups (Kashefi et al., 2012) and the students' Uz and Kundun, 2018). Thus, it enhances learning engagement (Alsalhi et al., 2021; Barros et al., 2017; Cronhjort et al., 2018) and improves the student learning experience (Attard and Holmes, 2020; Barros et al., 2017; Dziuban et al., 2018; Jeffrey et al., 2014; Mumtaz et al., 2017; Poon, 2013; Rifa'i and Sugiman, 2018). Furthermore, several studies have shown that applying blended learning to teaching improves student academic achievement (Alammary, 2019; Alsalhi et al., 2021; Balentyne and Varga, 2017; Gambari et al., 2017; Kundu et al., 2021; Lin et al., 2017; Poon, 2013; Psycharis et al., 2013; Zhang and Zhu, 2017). Several studies have confirmed that personality, learning style, and satisfaction positively affect progress in student achievement (Cheng and Chau, 2016; Vasileva-Stojanovska, 2015). For example, blending learning empowers students by building their capacity to communicate (Attard and Holmes, 2020; Dziuban et al., 2018; Kashefi et al., 2012; Kashefi et al., 2017), improving their thinking ability (Attard and Holmes, 2020; ElSayary, 2017, 2021), enhancing their mathematical problem-solving ability, and upgrading their technology application skills (Kashefi, 2012).

Blended learning is a teaching approach that positively impacts students' learning and teachers' instruction. Through individual interaction with students, teachers can see the learning needs of students, thereby allowing them to adjust or design lesson plans to suit students' learning progress (Attard and Holmes, 2020; Barros et al., 2017; Kerzič et al., 2019; Poon, 2013). Attard and Holmes's (2020) research demonstrated that teachers who participated in the survey could enhance students' access to math learning materials through digital resources. LMS enables teachers to access different representations of mathematics and apply alternative teaching methods through the innovation of learning spaces and teaching contexts (Attard and Holmes, 2020). At the same time, blended learning contributes to teachers' ability to apply information and digital technology to teaching (Attard and Holmes, 2020; Kashefi et al., 2012).

2.5. Challenges

For teachers and students most affected by the COVID pandemic and its unpredictable stages, the introduction of blended learning has many advantages. Nevertheless, there are certain difficulties in applying blended learning to math instruction. The research of Boelens et al. (2017) summarized the challenges in designing and implementing blended learning. In it, the author gives four main challenges, including flexibility in integration (in terms of time, place, and learning progress), interaction (face-to-face and online interaction), support of student learning (monitoring and assessing students) and creating an effective learning environment (creating motivation and encouragement, showing empathy, individualizing learning) (Boelens et al., 2017; Owston and York, 2018). Therefore, the application of blended learning often increases the teacher's workload, resulting in a large workload for teachers (Adiguzel et al., 2020; Attard and Holmes, 2020; Jeffrey et al., 2014; Nakamura et al., 2018; Poon, 2013; Sánchez-Gómez et al., 2019). On the other hand, the paucity of professional development to equip teachers with communication techniques, teaching strategies, and information technology skills necessary for online teaching and blended learning is also mentioned in the studies (Attard and Holmes, 2020; Poon, 2013; Psycharis et al., 2013; Sánchez-Gómez et al., 2019).

Students also experience difficulties when they are using blended learning. Nakamura et al. (2018) studied the pros and cons of blended learning when teaching mathematics and found that it is a significant inconvenience for students to use online learning systems to submit answers (such as CAS). The above technology issues are also raised by Poon (2013) and Psycharis et al. (2013). Poon's findings (2013) suggested that students do not find it motivating to learn online because of feelings of inauthenticity and isolation resulting from fewer lesson volumes and the lack of leadership. Students feel the need to become more authentically interconnected in the classroom. Also, learners cannot complete tasks because of lost time, the absence of individual problem-solving training, and a lack of social interaction when learning face-to-face (Poon, 2013).

On the other hand, research by Alsalhi et al. (2021) indicated that the effectiveness of the blended approach to students' learning depends on the levels of the students. Students with low grades may find it difficult to apply new teaching and learning strategies in blended learning, especially if they are not intrinsically motivated (Yusoff et al., 2017). Therefore, Yusoff et al. (2017) proposed a set of classroom measures that can be utilized to design blended learning activities best suited for various learning styles and levels of cognitive ability.

Furthermore, institutions of all types, such as schools and universities, are facing obstacles in meeting the diverse needs of blended learning. Many studies have shown that a shortage of technical facilities to support teachers and students in online learning is a significant barrier for those wishing to offer an online curriculum (Nakamura et al., 2018; Poon, 2013; Uz and Kundun, 2018). One solution to the potential obstacles associated with this approach to teaching is found in numerous studies that have proposed methods for schools and teachers that can be applied to blended learning. According to Kundu et al. (2021), math teaching activities and textbooks should connect to blend learning with teaching, especially as the teacher's understanding of each student's needs evolves (Kundu et al., 2021; Stahl, 2021). Teachers must feel confident and convinced of their online teaching environment capabilities.

Furthermore, teachers require pedagogical and technological skills to apply various information and communication technology (ICT) resources in teaching (Almerich et al., 2016; Bunatovich and Khidayevich, 2020; ElSayary, 2021). Therefore, educational institutions must provide instructional guidelines for using ICT in learning and develop pedagogical training for teachers so that students can effectively and confidently employ the software's various functions (Avineri et al., 2018; Kerzîč et al., 2019; Kundu et al., 2021; Naveed et al., 2020; Stahl, 2021). It is essential to provide course structures that give students the abilities and knowledge to work effectively with computers and online learning tools (Bunatovich and Khidayevich, 2020; Kerzîč et al., 2019; Naveed et al., 2020). Schools must equip teachers and students with the necessary tools for online learning (Kundu et al., 2021; Naveed et al., 2020), especially devices, so students can easily ask questions during the learning process (Attard and Holmes, 2020).

3. Context of the study

3.1. Conventions for coordinates in the plane in Vietnamese curricula and textbooks

Using the topic "Conventions for coordinates in the plane," students will learn about the equations of lines, circles, and ellipses and their properties to better understand geometric concepts. The spirit of the new teaching method is to encourage students to take the initiative and be creative, to follow students' activities in class, and to have students directly participate in acquiring knowledge. Using the teacher's organizational structure, students can identify problems and positively and creatively devise innovative solutions. Teachers' skills provide insight into their students' needs and allow teachers to design problem situations that allow students to discover new information. Therefore, students will retain information over a long time, clearly comprehend concepts, and be excited because they discover information, encouraging them to participate in additional activities. This topic requires students to accomplish the following goals. They must be able to derive equations of straight lines, circles, and ellipses from their graphs and vice versa; from the equation of a line, they must determine its characteristic elements; and they must apply their knowledge and use appropriate properties to solve related problems (Ministry of Education and Training, 2018).

Regarding knowledge of straight-line equations, students must:

- understand the normal vector of the line;
- understand how to write general equations or parametric equations of straight lines;
- understand the conditions under which two lines intersect, are parallel, coincide, or are perpendicular to each other;
- know the formulas to calculate the distance from a point to a line and the angle between two lines;
- know the characteristics of two points that lie on the same or opposite sides of a line.

Likewise, students should recognize and calculate the equation of a circle with a known center.

Finally, math learners should understand the ellipse, such as its definition and canonical equation, and be able to describe the shape of the ellipse.

Some important skills in this topic are as follows:

(1) Linear equations

- Write a general or parametric equation of the line d passing through the point $M(x_0, y_0)$ and having a given direction or passing through two given points.
- Calculate the coordinates of the normal vector if the coordinates of the direction vector of a straight line are known, or vice versa.
- Use a formula to calculate the distance from a point to a line.
- Calculate the measure of the angle between two lines.

(2) Equations of circles

- Write the equation of a circle when the center I (a, b) and radius R are known; conversely, determine the center and radius when the equation of a circle is given.
- Write the equation of a line that is tangent to a circle when the coordinates of the point of tangency are given; also, know how to write the equation of a line that passes through a point M outside a circle and is parallel to a given line that is tangent to the circle.

(3) Ellipse equations

From the canonical equation of the ellipse $\frac{x^2}{a^2}+\frac{y^2}{b^2}=1$ $(a > b > 0)$,

- Determine the major axis, minor axis, focal length, and eccentricity of the ellipse; identify the coordinates of the focal points and the intersection of the ellipse with the coordinate axes.
- Write the canonical equation of an ellipse given the characteristics of that ellipse (Ministry of Education and Training, 2012).

3.2. Teacher feedback about blended learning

A survey of 24 teachers in mathematics classrooms was conducted to learn more about their perspectives on blended learning. Twenty-one occasional teachers (accounting for 87.5% of the group), two regular teachers (8.3%), and one teacher (4.2%) indicated that homework assignments and online tests were rarely given. The rate at which teachers use the online form to give assignments and evaluate students is quite high. Because of the development of information technology, it is now simpler and more efficient to monitor and evaluate students' academic performance. In addition, the Ministry of Education and Training's new circular on diversifying testing and assessment contributes to the results mentioned above.

Regarding the level of satisfaction of teachers with the results of students' self-study, 17 teachers (accounting for 70.8% of the group) feel neutral, five teachers (20.8%) are not satisfied, and two teachers (8.4%) are satisfied. Furthermore, teacher satisfaction with the results of students' self-study is low because students have not mastered the skills they have attempted to learn in class, as well as the habitual reluctance of students to complete homework assignments. Because of this, it is essential to propose learning methods that assist students in developing their ability to self-study and work independently.

Regarding mathematics instruction with a blended learning approach, 12 teachers (50% of the group) think it is appropriate, ten teachers (41.7%) believe it is very suitable, and two teachers (8.4%) believe that it is very appropriate. According to the data, a very high percentage of teachers favor this blended learning method of instruction.

Regarding the effectiveness of online lessons during the recent COVID-19 pandemic, 15 teachers (62.5%) commented that they were quite effective, while five teachers (20.8%) were neutral, and four teachers (16.7%) commented that the online lessons were effective. The success of online education has been low in recent years, and this is because neither educators nor students are very well versed in or prepared for this novel approach to education. Also, the ineffectiveness of online teaching and learning can be explained by the following reasons:

1) Twenty-two teachers (accounting for 91.7% of the group) find it difficult to interact with students.

2) Thirteen teachers (54.2%) feel that students are not cooperative in the learning process.
3) Twenty teachers (83.3%) feel that online assessment has not yet ensured objectivity and has not properly assessed students' abilities.
4) Ten teachers (41.7%) find it difficult to use tools and software for designing online lessons.
5) There are two other opinions: it is more difficult to convey content knowledge than direct instruction in the classroom, and preparing lectures takes time.

3.3. Research questions

These are the questions that the research sought to answer:

(1) How does blended learning improve students' learning activities and academic achievement?
(2) How does blended learning motivate the development of students' self-study abilities?
(3) What are the attitudes of students in the experimental group toward using blended learning for mathematics instruction?

4. Method

4.1. Research design and sample

An experimental research design was conducted in this study to investigate the effectiveness of blended learning in teaching mathematics about students' academic achievement, self-study skills and learning attitudes. In experimental designs, an experimental group and a control group are determined by a pre-test, intervention, observations and attitude survey are carried out in the experimental group, the lessons are taught in the control group, and the results of a post-test in both groups are compared. The research study was based on various empirical research methods scrutinized in the Literature Review and the educational context in Vietnam. This research demonstrates that examining educational innovations is commonplace in educational research (Tesch, 2016). For this study, the researchers used a quasi-experimental design with a controlling technique different from randomization, such as a counterbalanced design (Chusni et al., 2022; Fraenkel et al., 2012).

With the approval of the Institutional Ethics Committee of the School of Education at Can Tho University, a two-group experiment was conducted with 10th-grade students from Doan Van To High School in Soc Trang province, Vietnam, from January to March 2021 to answer the research questions. Especially all participants and their patients consented to participate in the experiment after receiving adequate explanations. Besides, participants in the study had shown an interest in and willingness to engage in classroom activities. Additionally, this study discovered that neither disrespect nor prejudice toward students was examined, and neither had any unfavorable effects on them.

The sample comprises 90 students in the 10th grade between 14 and 15 years old, with 44 students (20 males and 24 females) in the experimental group and 46 students (22 males and 24 females) in the control group. Students in experimental groups were coded as S01–S44, according to the alphabetic order of their first names. It was very challenging to collect data because high schools were typically closed during the pandemic. These challenges impede the effective advancement of research. Because of this, the convenience sampling method was applied to collect accurate data that fit the study's parameters. The convenience sampling method is recommended for quick, easy, and economical data collection.

4.2. Data collection and analysis

For the research mentioned above objectives, some of the tasks were outlined. The researchers developed a pre-test and a post-test to administer to an experimental group while a control class was assigned to solve the pre-test. An experimental lesson plan will be developed to enhance the students' academic achievement and self-study abilities. The research team was responsible for teaching, observing, and collecting information reflecting the experimental process related to the practicability and efficiency of the teaching process. Observations were made in two categories: the students' participation in learning activities and the students' ability to self-study regularly. During online lessons, teachers monitor their students' activities and make use of a checklist to track the frequency with which their students complete their assigned worksheets as well as the students' engagement in learning activities following the instructions of the teacher (delivered online and offline). The criteria for assessing students' worksheets are shown in Table 1. Finally, the students in the experimental class were given a survey to evaluate the above teaching activities. In order to obtain data on students' learning attitudes, the students were asked to rate how much they agreed or disagreed with four given statements about the application of blended learning, which were assessed on a 5-point Likert scale: Strongly disagree, Disagree, Neutral, Agree, and Strongly agree (Likert, 1932). These instruments were created by Pambudi and Hobri (2012, as cited in Pambudi, 2022). The survey was created and distributed using the Google Forms program, and students in the experimental group were required to complete it. Data from the pre- and post-tests, worksheets, observations, and survey results were collected and analyzed quantitatively and qualitatively as evidence to answer the research questions.

The data from the pre-and post-tests were analyzed quantitatively. A quantitative analysis was attached to the t-test in the SPSS Statistics 20 program to examine the difference in mean values between the experimental and control groups. Furthermore, the effect size (ES) (Cohen et al., 2011) was used to measure the pedagogical impact on the academic achievement of the two groups, and the correlation between the two tests administered to the experimental class was addressed. On the other hand, qualitative analysis was carried out on the data obtained from the students' worksheets, observations, and surveys.

4.3. Research experimental process

The experimental process includes the following stages:

(1) Selection of experimental class and control class.
(2) Prepare lesson plans, online lectures, and materials for the experimental process.
(3) Conduct experimental group instruction on learning methods and provide necessary knowledge and skills when learning online.
(4) Teach the in-plane coordinate method for the experimental class through a flex model in blended learning. At the same time, teach this topic to the control class with face-to-face learning and traditional lesson plans.
(5) Conduct classroom observations to assess students' learning attitudes and self-study abilities. Hand out exercise worksheets (online and offline forms) and collect and analyze students' worksheets to regularly assess academic achievement through short exercises.

Table 1. Criteria for assessing student work.

Unfinished	Fairly well done	Well done
Students are not finished if the following conditions are met: - Students do not work seriously or look at each other's work. - The result of the test is less than 5 points. - Assignments are not submitted.	Students do quite well if the following conditions are met: - Students take their homework seriously. - The result of the test is between 5 and 8 points. - Assignments are submitted on time.	Students do well if the following conditions are met: - Students take their homework seriously. - The result of the test is over 8 points. - Assignments are submitted on time.

(6) Organize post-tests, survey students' opinions of the experimental class, and evaluate experimental results.

After consulting with teachers at the school about the level of math learning in the classes, the research team selected two classes to conduct experiments. The experimental and control groups' input quality was tested with an objective multiple-choice test to determine whether it was equivalent to that before the experiment started.

Furthermore, since designing the experimental plan based on the actual situation would prepare students for online learning, the experimental group was surveyed to identify their problems before starting the experiment. Some of the questions used in the survey include:

(1) How much time do you spend on self-study at home?
(2) What time of day do you often use for self-study?
(3) What personal information technology do you regularly use to participate in online learning?
(4) What are your difficulties in the online learning process?

Online lessons are conducted through Google Classroom software. A common assessment method in online learning is to have students display their work on personal notebooks and send them to teachers using photos.

The two groups were pre-tested for 45 min in the same classroom setting to evaluate the experimental outcomes. Students were asked ten multiple-choice questions and three short-answer questions in the post-test. The researchers adapted these conceptual comprehension questions from previous state-level trial examinations to fit their needs. In addition, the test question items were created by the level of Anderson Taxonomy used. The researchers also devised a rubric for the conceptual comprehension test's scoring technique. A total of four mathematics teachers with over 15 years of experience in the classroom, and two mathematics lecturers who were content experts on the topic of coordinates in the plane, reviewed and rated the instrument and this rubric to determine its content validity. Based on the testing results, it will be possible to determine whether or not the proposed self-study training method will be effective and the extent to which students have achieved mastery. Validation and testing were required before the experiment could be confirmed as successful. In order to research this issue, researchers developed reliable, high-quality instruments. Two experts in mathematics education confirmed that the exams were valid. In the study conducted by Yatim et al. (2022), the method of obtaining facial and content validity based on mathematical experts was done similarly. The experts' panels were asked to respond to research questions by completing a questionnaire and providing their thoughts or comments. Academic achievement, lecture design, instructing strategies, and blended learning activities were some topics covered in the questionnaire. Several alterations were made to the instruments and research, and the whole process was evaluated to ensure it was successful. All the experts who examined the instrument reported that it had not been revised, and they all concurred that it was suitable. After much deliberation, they finally agreed to re-evaluate the tests based on their usefulness for the research topic. Also, researchers could evaluate academic and skills content across all topics, such as linear equations and equations of circles and ellipses.

The participation of the students in learning activities and the students' abilities to consistently engage in self-study were the two main areas of focus for the observations. Students participate in online lessons to acquire knowledge, complete online (homework) and offline worksheets, contribute to class discussions and use various online sources to find answers to assigned problems. Teachers keep a close eye on students' online behavior and use a checklist to record whether or not they are actively participating in the lessons, whether or not they are completing their worksheets (both online and offline), and whether or not their grades improve as a result of their increased ability to study independently. Finally, after having participated in the practical lessons for a total of two months, the students assigned to the experimental group were given a set of survey questions to answer to provide feedback on the lessons in which they had taken part.

5. Results

5.1. Pre-test results

The experimental group's pre-test scores were compared to those of the control group using SPSS software to determine a statistically significant difference between the two groups' scores. Descriptive statistics show that the mean of the experimental and control classes are 8.02 and 8.09, respectively, and there is no significant difference. The sig. value in Levene's test is equal to $0.777 > 0.05$; hence the experimental and control groups do not differ. With a significance level of 0.05, the test results show that the sig. value (2-tailed) equals 0.815 (Table 2). Therefore, the mean score difference between the two groups was not statistically significant. In other words, the mathematics learning level of the two groups is equivalent and is, therefore, suitable for conducting experiments.

5.2. Quantitative assessment of post-test results

The following score distribution chart (Figure 1) shows the experimental and control group results.

The experimental group received a higher average score than the control group, as illustrated by the graph plotting the frequency of test results after 45 min. The frequency of experimental group scores is distributed around the value 8–9, and the corresponding value in the control group is 6–7. For every experimental class with a frequency above 8–9, the number of re-scores will be higher than in the control group; for every experimental group with a frequency between 6-7, the number of re-scores will be lower than in the control group. The frequency of scores of the control group is mainly distributed at the average and good levels. Compared to the experimental group, fewer students in the control group received high marks. No student scored 10 points, although the experimental group had two papers totaling 10 points, which deserves special notice. Thus, it is possible to demonstrate that the student's mastery and understanding of the lesson in the experimental group are better than that of the students in the control group. In addition, the graph of the frequency of convergence of the scores of the test appears as follows:

The graph in Figure 2 shows that the experimental group's test scores are higher than those of the control class, indicating that the experimental students performed better on the tests. Furthermore, an independent t-test was conducted to test the null hypothesis, which states that test scores should be equal for the experimental and control groups and to see if the experimental results are correct. The following data in Table 3 depict the independent t-test results of the mean scores of the two groups.

Table 2. Results of independent t-test of the pre-test.

Group Statistics					
Group	N	Mean	Std. Deviation	Std. Error Mean	
Experimental group	44	8.02	1.338	0.202	
Control group	46	8.09	1.262	0.186	
Levene's Test for Equality of Variances					
F				Sig.	
0.081				0.777	
t-test for Equality of Means					
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	-0.234	88	0.815	-0.064	0.274

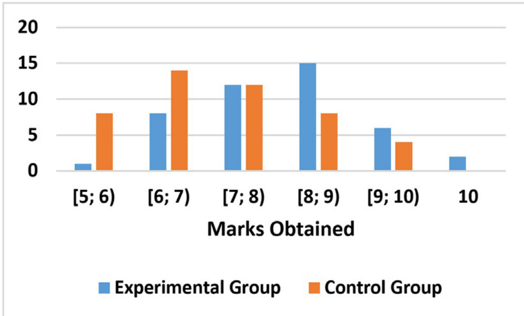

Figure 1. Score distribution chart of the experimental and control groups.

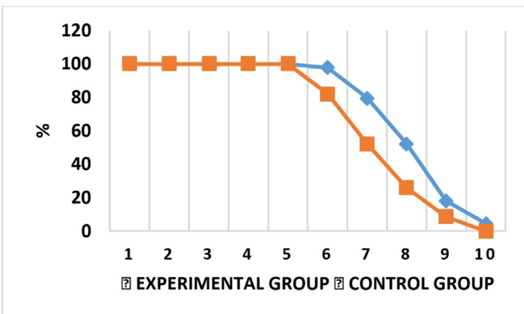

Figure 2. Frequency of convergence of the test scores.

Table 3. Results of independent t-test of post-test.

Group Statistics					
Group	N	Mean	Std. Deviation	Std. Error Mean	
Experimental group	44	7.7864	1.15307	0.17383	
Control group	46	6.9630	1.22590	0.18075	
Levene's Test for Equality of Variances					
F				Sig.	
0.041				0.840	
t-test for Equality of Means					
	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Equal variances assumed	3.279	88	0.001	0.82332	0.25112

The mean difference in the post-test scores of students in the experimental and control groups was tested utilizing an independent t-test with SPSS software. Descriptive statistics show that the mean value of the experimental and control classes is 7.7864 and 6.9630, respectively, and it is obvious that there is a difference. There is no distinction between the experimental and control groups, as determined by the sig. value in Levene's test, which equals $0.840 > 0.05$. With a significance level of 0.05, the test results show that the sig. value (2-tailed) equals 0.001 (see Table 3). Therefore, the mean score difference between the two groups was statistically significant. Therefore, the null hypothesis is rejected, and the alternative hypothesis is accepted. Thus, the two groups' math academic achievements after the experiment differed. In particular, a mean deviation of 0.82332 between the experimental and control groups indicated that the experimental group had better academic achievement than the control group.

Furthermore, the effect size (ES) (Cohen et al., 2011) was used to measure the pedagogical impact on the academic achievement of the two groups. With a standard mean difference (SMD) of 0.6717, it can be

Table 4. Correlation between two tests of the experimental class.

		Pre-test EG	Post-test EG
Pre-test EG	Pearson Correlation	1	0.867**
	Sig. (2-tailed)		0.000
	N	44	44
Post-test EG	Pearson Correlation	0.867**	1
	Sig. (2-tailed)	0.000	
	N	44	44

** A significant correlation is found with a p-value of 0.01 (2-tailed).
** EG: Experimental group.

concluded that the experimental effects moderately influence the results of the two groups. As a result, it can be concluded that the experimental group's academic performance is better than the control group's based on the coordinates in the plane. By this, it can be understood that the application of blended learning has improved students' ability to study by themselves, allowing them to refine their knowledge and skills further and, therefore, facilitating their improved academic performance over those of the control group. Blended learning has improved students' self-study skills and academic achievement, which addressed research question 2 and, in part, question 1. Furthermore, the correlation between the two tests administered to the experimental group was addressed.

The correlation test results from Table 4 show that, with the sig. level (2-tailed) less than 0.05, experimental group scores in the two tests before and after the experiment are correlated. Accordingly, the Pearson correlation coefficient equals 0.867, showing that the correlation is strong. Furthermore, based on Figure 3, the majority of the above scores are distributed about the line, indicating that students in the experimental group who achieved high scores in the pre-test would similarly achieve high scores in the post-test.

5.3. Experiment results

During the experiment phase, worksheets from students were collected and subjected to a qualitative analysis. Because the content of the experimental process is quite long and the amount of students' work is relatively large, the study only presents the analysis and qualitative assessment of the results of the students' work through two cycles of the reinforcement exercises No. 1 and No. 2. Both exercises were computational written questions. In exercise No. 1, students were asked to write the equation of a line passing through two points given to them in

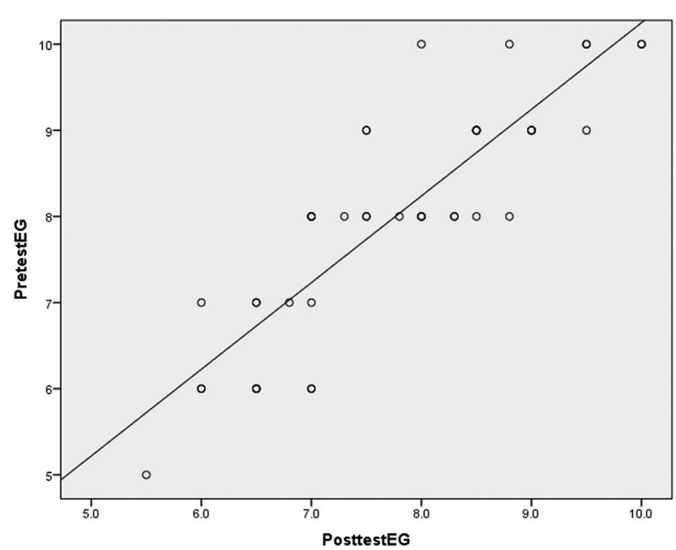

Figure 3. Scatter chart of experimental group data.

Table 5. Experimental results of exercise No. 1.

Levels	Unfinished	Fairly well done	Well done
%	27%	41%	32%

Table 6. Experimental results of exercise No. 2.

Levels	Unfinished	Fairly well done	Well done
%	7%	43%	50%

advance. When it came to exercise No. 2, students were asked to solve a broader range of problems, including finding the orthogonal projection of a point onto a line, writing the equation of a line passing through a given point while parallel to another line, and calculating the distance between a given point and a line.

After completing three periods of the lesson on equations of lines, students were asked to do the online reinforcement exercise at home for 60 min, and the following results were obtained. The criteria for assessing student work are shown in Table 1.

Table 5 shows that, in contrast to what was seen in Table 4, the number of students who had not completed the experiment was also very high (12/44). The grades of three additional students were lower, and one did not submit their test. A total of seven students swapped assignments with each other. It has been found that, by learning through online lectures and classroom lessons, many students increased their ability to apply their knowledge to solving math problems and presenting them on paper.

Figure 4 illustrates how student S02 mastered writing a general equation after self-study with online lectures on a straight line. However, her work was still quite faulty, and the problem solution was incorrect because it demonstrated that point *B* coordinates are the coordinates of the normal vector of line *d*. After completing all of her assignments in class with real-time corrections and feedback, she concluded her work, and it was found that she grasped the concepts and could use them to solve problems successfully. Since the results show that students in the experimental group did not demonstrate high learning efficiency when learning online at the early stages of becoming acquainted with blended learning, it can be assumed that students are less efficient learners when they first become acquainted with blended learning. They reinforced their learning in the face-to-face class through direct interaction with students. However, students' level of knowledge after online lessons was relatively good, which was a positive indication that the application of the flex model had achieved initial effectiveness.

Despite this degree of success, it was revealed that most assignments contained identical errors, as shown in Figure 5. Because the reinforcement exercise was done at home, students could see and present the same things by sharing papers.

Despite this unexpected result, it was also a useful point of departure for the experiment; research by Adiguzel et al. (2020) on this issue also mentioned it. The researchers modified the instructional strategies and teaching measures to meet the students' learning interests and needs. Correspondingly, the research team improved communication and interaction between teachers and students, allowing students to know the teacher's enthusiasm for each student's progress. As a result of being encouraged to take on independent learning assignments, more students realized the value of developing their study techniques.

After assessing the students' work for reinforcement exercise No. 2, the research team obtained the following results.

Table 6 shows that the percentage of students whose work was considered "Well done" had increased considerably (from 32% to 50%) when compared with reinforcement exercise No. 1. The percentage of students who did not complete exercise No. 2 declined considerably (only 7%); here, two students received poor grades, and one student was absent (with permission). Blended learning made students comfortable with the blended approach and increased their ability to work independently.

To test the students' ability to self-study and search for solutions, the problem "Find the coordinates of the perpendicular projection of a point on the line" was given after the third and fourth periods of the class with no instructions given. Therefore, only a few students finished the problem but had great difficulty explaining how they solved it, and many students could not solve it. Some students became proficient in presenting the solution, but they had viewed the solution guide during the practice session of the online lecture and were, therefore, able to solve the problem (refer to Figure 6).

The findings discussed above can be used to make the following observations. The methodologies employed for most students were not sufficient to yield comprehensive results regarding self-study and self-

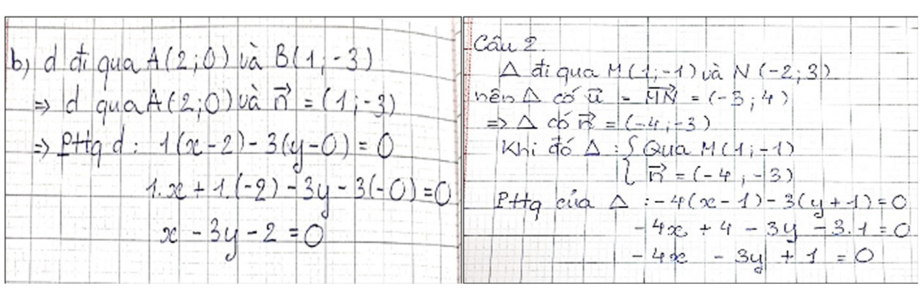

Figure 4. The work of student S02 after learning through online lectures and studying in class.

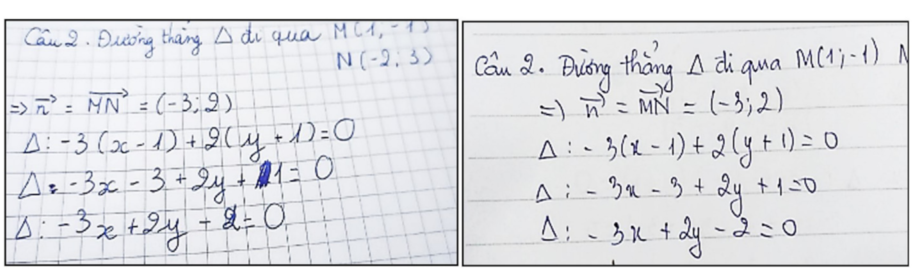

Figure 5. The work of students S11 and S27 has the same presentation and errors.

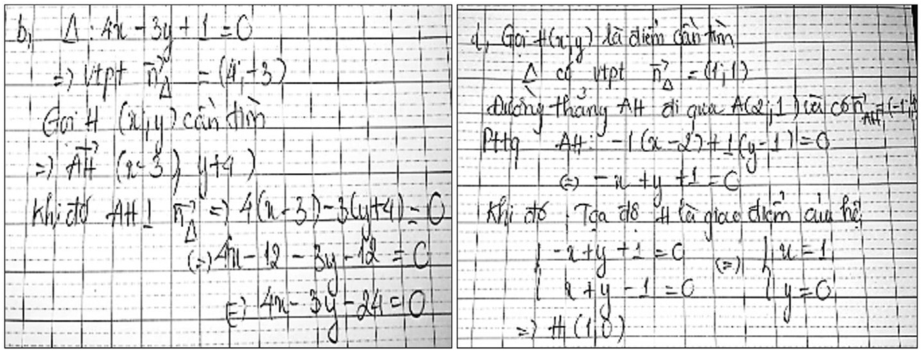

Figure 6. S25 student's work before and after instructions from the online lecture.

analysis. Many students discovered the value of watching online lectures and understanding those lectures. Students improved their academic achievement by using online lectures, which allowed self-study to become more efficient and interesting.

Moreover, after the teacher gave feedback on the results of reinforcement exercise No. 1, the students in the experimental class no longer showed signs of referring to each other's work during reinforcement lesson 2; the exercises were prepared more precisely, and each student's approach to problem-solving exhibited more independence (Figure 7). By completing their homework more quickly, the students in the experimental class improved their ability to work through their homework the first time they learned to use blended learning. Results from this study contributed to the development of answers to research questions 1, 2, and 3.

5.4. Observation results

Through online and classroom methods, the teachers in the experimental class learned about students' learning attitudes and assessed the effectiveness of math learning, which led to an answer for research questions 1 and 2 about improving students' learning activities and self-study abilities.

Category 1. Students' participation in learning activities.

Overall, students' main motivation for enrolling in online lessons was their anticipation of seeing visual images created by teachers. As students' understanding of the lesson improved, they became more open when speaking with the teacher and participating in group discussions.

The results show that the class atmosphere was quite lively while knowledge consolidation lessons were taking place. Furthermore, observations showed that most students remembered the information presented in the online lecture and expressed it in their own words after the teacher repeated it. Students applied their knowledge quickly and discovered solutions; they confidently offered their viewpoints and requested answers from teachers.

Most students were more active than passive with their teachers when providing feedback about their academic advancement. The research team concluded that this could be expected due to the blended learning method.

Category 2. Students' self-study abilities.

Students studied online before class, and their understanding of the lectures became much more complete. They were confident about their views, which led to discussion and an exchange of views on issues they did not understand, allowing them to gain knowledge and practice their communication skills.

They proved that they had improved their self-study and learning efficiency when they were able to work through the lessons. Students were well aware of the Internet's numerous resources for studying the lesson and finding math solutions. Independent learning is demonstrated in the work of these students who learned while applying blended learning methods.

The experimental class students achieved high self-study skills by having favorable attitudes, personalities, and aptitudes. Regarding attitude, they took personal responsibility for their learning, were bold and confident in taking on new challenges, and desired to learn more. Students exhibited an eagerness to learn and were proactive in demonstrating academic achievement. They were self-disciplined, determined, and confident, fulfilled their goals, enjoyed learning, and had a high level of curiosity. Students have skill sets that include classroom activities, managing their learning time and planning strategies. Self-study ability is also an aptitude, an inherent quality of each individual. However, this ability changes depending on the individual's use of blended learning. Because of this, students' ability to do independent research will be the central foundation that determines their success on the path ahead and helps them learn throughout life.

5.5. Student opinion survey results

After teaching the conventions for coordinates in the plane in the experimental class, we conducted a survey in the experimental class regarding the students' interest in blended learning.

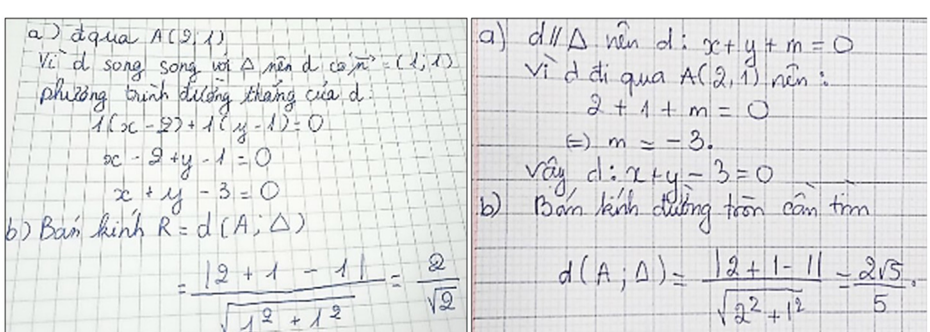

Figure 7. The work of students S11 and S27 in reinforcement exercise No. 2.

Table 7. Student responses to Item 1.

Levels Items	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Item 1	0%	7%	18%	59%	16%
Item 2	0%	9%	27%	43%	21%
Item 3	0%	4%	46%	41%	9%
Item 4	0%	4%	43%	43%	10%

Item 1. I am interested in learning the coordinates in the plane with classroom learning combined with online lectures.

Based on Table 7, it can be observed that after students in the experimental class learned the conventions for coordinates in the plane with the application of blended learning, most of them felt more interested than when the traditional way of learning was applied (accounting for 59% of students). In particular, 16% of students thought this learning form interesting. In addition, some students (18%) found these two ways of learning equivalent, while a few (7%) appeared to be more interested in the conventional way of learning.

Item 2. I am satisfied with the quality of the online lectures that I have listened to in Google Classroom (content, audio, images).

The numbers in Table 7 show that 43% of students surveyed reported that they were satisfied with online lectures, and 21% reported being very satisfied, which illustrates that lectures were thoughtfully created with full content, were easy to understand and that students had a better understanding of the content when self-studying at home. However, a few students were still not satisfied with the quality of the lectures (9%), which means that the lectures still had a few areas that needed to be reconsidered or because this was a relatively new form of learning with which they were not familiar.

Item 3. Studying the conventions for coordinates in the plane employing blended learning helps me master and deeply understand the knowledge and skills needed to solve the learned math forms.

Nearly half of the students felt no difference between classroom learning combined with online lectures and the conventional learning method, whereas 41% agreed with Item 3. Nine percent strongly agreed with this method of learning, which helped them to master the knowledge they learned and improve their math problem-solving skills. These results show that the best way to assist students in learning is through a blended learning method that combines in-person instruction with online lectures (see Table 7).

Item 4. I find that classroom learning combined with online lectures will develop my self-study ability and make me feel more interested and effective in learning.

Based on Table 7, the results show that most students agreed and strongly agreed (53% altogether) that blended learning positively impacted their ability to pursue self-study. This form of learning was highly supported and loved by students. They appreciated and respected it and recognized its benefits. In addition, some students thought there was no difference between this form of learning and the traditional way of learning (43%), and a few thought this form was ineffective (4%). This valuable feedback was extremely important for the research team, helping it to examine the experimental design and instructional methods carefully. In addition, these conclusions answered research question 3.

Moreover, some studies also found that students saw no difference between blended and comprehensive face-to-face learning (Alammary, 2019). Given the need to use blended learning to cope with the fluctuations of the COVID-19 pandemic, which may affect students' school attendance, this is still considered a positive result. Thus, online distance learning helps students acquire knowledge, which supplements but does not completely replace classroom learning.

6. Discussion and limitations

The survey results and the knowledge gained in the classroom indicate that integrating blended learning into the protocols for the coordinates in the plane initially led to an improvement in the caliber of the learning activities carried out by the students. Blended learning helped students be more active in interacting with teachers by enhancing teacher-student communication online and through classrooms and interactive channels on social networks such as Facebook and Zalo (Alammary, 2019; Alsalhi et al., 2021; Attard and Holmes, 2020; Barros et al., 2017; Hoyos et al., 2018; Kashefi et al., 2012; Miyaji, 2019; Mundt and Hartmann, 2018; Rifa'i; Sugiman, 2018; Sánchez-Gómez et al., 2019). When students' learning needs are heard, this is a great motivation to participate in learning activities actively (Alsalhi et al., 2021; Barros et al., 2017; Cronhjort et al., 2018). Additionally, students can flexibly arrange study time and space (Akpan, 2015; Sánchez-Gómez et al., 2019; Uz and Kundun, 2018; Zhang and Zhu, 2017). Because of this, students have a more optimistic and self-assured approach to learning, whether attending a class in person or participating in an online discussion. This result is also indicated in several studies (Alammary, 2019; Alsalhi et al., 2021; Alsalhi et al., 2019; Attard and Holmes, 2020; Balentyne and Varga, 2017; Lin et al., 2017; Mumtaz et al., 2017; Uz and Kundun, 2018).

Moreover, experimental studies have demonstrated that blended learning helps students improve their ability to work independently and their capacity for self-study. Many students relied on the assistance of their teachers, fellow students, and classmates because the blended learning model made it difficult for them to comprehend the material and find solutions to their problems. Nevertheless, many students found that their capacity for independent learning significantly increased by spending more time studying online and receiving support for both self-study and teacher-led self-study. Their research greatly enhanced the student's independent thought and creative problem-solving capacity. This is an accurate outcome in line with what was observed in the study (Balakrishnan et al., 2021; Hori and Fujii, 2021; Kundun, 2018). In the area of knowledge, the findings of earlier studies regarding the superiority of traditional learning over blended learning in terms of attaining higher academic achievement were inconsistent (Alammary, 2019; Alsalhi et al., 2021; Balentyne and Varga, 2017; Gambari et al., 2017; Kundu et al., 2021; Lin et al., 2017; Poon, 2013; Psycharis et al., 2013; Zhang and Zhu, 2017) or equivalent (Alammary, 2019). In the framework of this study, given a rather small sample (fewer than 50 students) and in the condition that students have been familiar with online learning before, the experimental results have shown that students in the experimental group were superior to those of the control group, although the differences were not drastic. These findings align with the poll of student opinions taken in the class. In almost all survey questions, respondents said they had better efficiency when they learned online than face-to-face. The flex model enables educators and learners to create lessons that help students solidify their knowledge while giving them immediate feedback on how they are doing. Because of the resources and information teachers obtain through online interactions, they can assist students whenever required (Adiguzel et al., 2020; Barros et al., 2017; Kerzič et al., 2019). In light of the increasingly complex conditions currently affecting the epidemic, the many different learning models available through blended learning are appropriate choices for teachers and students to follow to make safe and reasonable educational progress. These findings answer the research questions, indicating that blended learning positively affects students' learning activities, academic achievement, and self-study abilities, as well as students' recognition of the higher level of mathematics understanding and academic outcomes gained through blended learning compared to face-to-face learning. Accordingly, it can be said that the experiment's findings support the viability of using blended learning to teach mathematics in a classroom setting.

Despite this, there were still some restrictions regarding putting this unified instructional model into practice. It is reasonable to assume that students and teachers will be uncertain about using new technological devices and software within an educational setting because such tools are (Attard and Holmes, 2020; Poon, 2013; Psycharis et al., 2013;

Sánchez-Gómez et al., 2019). On the other hand, learning effectiveness depends greatly on students' active learning attitude and self-study abilities (Cheng and Chau, 2016; Vasileva-Stojanovska, 2015); teachers can use the allowable duration of the experiment but not yet promote a positive learning attitude and improve the self-study abilities of each student. Because of this, the experiment cannot have a meaningful impact on all of the students who participated. In addition, given the limited number of samples used in the experiment, the experiment's results may only represent a subset of the population.

Therefore, it is important to acknowledge the constraints of blended learning to ensure its applicability in the real world, and preparations over the long term are required. Based on initially researching and implementing blended learning at high schools during the period of social distancing due to the epidemic, the research team considers it necessary to identify the blended teaching model as a new strategy for a learning society that needs attention and improvement. As a result, blended learning is a suitable strategy for teacher training institutions and educational managers to improve the quality of training for teachers, particularly pedagogical students, in utilizing information technology in the classroom. If students and teachers alike are interested in making the most of the opportunities presented by modern information technology in the classroom, they must have the appropriate training and resources. In addition, developing students' knowledge and abilities in the appropriate use of technology at the appropriate time is an additional necessary factor to increase the efficiency of online learning. On the other hand, for educators to successfully meet the demands of distance learning promptly, they need to emphasize enhancing their professional capacities, cultivating their technological abilities, and regularly updating themselves on the latest teaching trends.

7. Conclusions

The experiment's results with a sample of 90 students in the tenth grade confirmed that blended learning had improved students' self-study skills and academic achievement. The t-test analysis of the post-test results for the two groups, using a significance level of 0.05 and a sig value (2-tailed) of 0.001 (see Table 3), demonstrated that the experimental group was successful in attaining higher academic achievement than the control group. In addition, the experimental group's results. Consequently, it can be concluded that the application of blended learning has improved students' self-study abilities, allowing them to refine their mathematical knowledge and skills and improving their performances. Students learning attitudes, self-study abilities, and academic achievement all improved as a result of blended learning, as indicated by observations and a survey of students' opinions, which also indicated that blended learning had increased student interactions with teachers. Due to the novelty of the new method for both students and teachers, the study still had some limitations that prevented it from significantly impacting. In addition, the experiment's results might only be representative of a subset of the population due to the limited size of the sample.

A positive impact has been made on learning efficiency, as well as the stimulation of a positive learning attitude and the development of student's ability to study on their own, thanks to the teaching model that has been combined with a system of lesson plans and lectures designed to suit online teaching and supported by Google Classroom. The ability of students to conduct their research and engage in self-discovery with the assistance of technological tools is one of the characteristics of blended learning models that can vary significantly depending on the model used. One more characteristic of blended learning models that can contribute to increased student achievement is improving the communication between teachers and their respective classes. In addition, they are less expensive, simpler to implement, and superior for educational purposes. The results of this study lend credence to the characteristics of blended learning, and the conclusions drawn from it call for the creation of specialized software, websites, and other resources of a similar nature that can be utilized by both instructors and students in particular models of blended learning.

The findings of this study supported the efficacy and applicability of blended learning and the flex model in the context of mathematics education in Vietnam, which encourages Vietnamese math and other subject educators to integrate blended learning into their instruction. The findings of this study can also be used as a guide by educators considering incorporating blended learning strategies into their lesson plans. The literature review also helped shed light on the pros and cons of various blended learning models, which aided educators in making informed decisions about which models would be most effective in a given setting. From managerial insights, the results of this study indicate that it is applicable to adopt blended learning in the mathematics curriculum, which may lead to changes in the subject's curriculum, teaching plans, and professional training plans for teachers. Moreover, the applicability of the flex model in teaching mathematics may provoke their interest in investigating the effectiveness and applicability of other blended learning models in teaching, leading to further studies on the application of different blended learning models in mathematics education.

When implementing blended learning in the classroom, additional studies can concentrate on researching or developing software and websites to deal with teaching and learning within blended learning models, identifying additional solutions to ease the workload of teachers, and drawing conclusions when applying blended learning in subjects or grades where technology devices may be a challenge for teachers and students. Additionally, research issues that can be considered include expanding the scope of research on the influence of blended learning on other subject areas or conducting the study with larger sample size.

Declarations

Author contribution statement

Duong Huu Tong: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Bui Phuong Uyen: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Lu Kim Ngan: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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