BLENDED LEARNING OF AC CIRCUITS FOR TRANSFER STUDENTS FROM THAI-KOSEN TO JAPANESE KOSEN

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This article reports on a blended learning of AC circuits. The course is designed for the selected second-year Thai-KOSEN students who are directly transferred to the third year of Japanese-KOSEN by bypassing an extra education. On the way, the students face two barriers in the transfer: one is the Japanese language, and the other is the curriculum gaps.

For example, if a student belongs to the Mechatronics engineering department in KOSEN-KMITL or the Automation engineering department in KOSEN-KMUTT, where AC circuit is not taught in the second year, is transferred to one of the Electrical departments in a Japanese KOSEN, where the first course of AC circuits is taught in the second year, the student starts from the second course of AC circuits in Japan. The first course of AC circuits, including phasors, impedances expressed by complex numbers, and circuit analysis, is not only the vital foundation for the succeeding courses of AC circuits but also a challenging course for students to learn by themselves. The extra 'AC circuit' course is one of the courses that fills in the curriculum gaps. It started in the 2023 Academic Year (AY) with nine one-hour face-to-face lessons for KOSEN-KMITL students and remote lessons for KOSEN-KMUTT students. As the students' timetable is fully packed with regular courses, the extra course was set in the evening after the regular lessons during the three months from December to February. It became a lecture on basic concepts and analysis techniques of AC circuits because of the limited time. The students did not have time to explore the circuits during the lessons.

In 2024 AY, we changed the teaching style to blended learning, combining on-demand lecture videos with face-to-face exercises for KOSEN-KMITL students. Nine-hour lectures are divided by topics into 40 video clips and served through MS Teams with the teaching materials and exercise sheets, which are provided two weeks before the face-to-face exercise sessions. The students are expected to watch the videos before the exercise sessions and are ready to tackle the exercise questions immediately at the start of the exercise sessions.

The blended learning worked well for the course, possibly because the students were highly motivated to learn the subject and well-informed about the necessity from those who had transferred to Japanese KOSEN in previous years.

Keywords: *blended learning, AC circuits, transferring students, curriculum gap*

Introduction

The National Institute of Technology (NIT) set up a program to accept the top 17% of Thai KOSEN students directly into the third year of Japanese KOSENs after completing their second year in a Thai KOSEN. The program aimed to unite KOSENs in the two countries into a single system and encourage young Thai students to work internationally.

The transfer students face two hurdles to overcome when learning in Japanese KOSENs. The first obvious hurdle is the language used in teaching. Almost all Japanese educational institutions use Japanese as the teaching language, and KOSENs are no exception. Because of the language barrier, international students usually take one year of intensive language courses in Tokyo before starting their KOSEN studies. However, the transfer program from Thai KOSENs does not include those intensive language courses. Instead, the students from Thai KOSENs must learn the Japanese language in and out of their regular language lessons during the two years in Thailand. Although they also receive additional language lessons before they are transferred to Japan, the engineering terminologies and typical expressions used in engineering subjects are out of reach in the regular language lessons.

The second hurdle is the curriculum gaps between the Thai KOSEN and the host KOSEN in Japan. Serious gaps exist in programming language C and AC circuits courses for some transfer students. For example, second-year students of the Mechatronics Engineering department (ME) at KOSEN-KMITL in Thailand learn DC circuit analysis in their second year, but AC circuits in the third year (KOSEN-KMITL, 2025a). On the other hand, some host KOSENs in Japan teach the first course of AC circuits during their second year (NIT, 2025). As the transferred ME students do not stay in the third year in

Thailand or the second year in Japan, they miss the opportunity to take the first AC circuits course by transferring from Thailand to Japan.

The first course of AC circuits, as is Electromagnetism, is recognized as a challenging course in Electrical Engineering. The difficulty comes from using a mathematical expression called a phasor, which is expressed by a complex number or a rotating vector in the complex plane, to represent an AC wave such as an electric voltage or a current. The relation between an AC voltage and current is also expressed by a complex number called an impedance. Because of these representations, we can use the analytical methods used in DC circuit analysis, and AC circuit analysis becomes simpler. However, novice learners sometimes have difficulty understanding the relationship between a sinusoidal wave and a phasor and take time to use the representation confidently.

As the first course on AC circuits is not an easy subject for students to learn by themselves, NIT prepared an extra course on AC circuits for transfer students. The additional course is designed as nine weekly lessons of one hour each after the regular lessons in Thai KOSENs. The ME students are to learn AC circuits in the additional course in parallel with DC circuit analysis in their regular course. The jam-packed timetable of the regular courses and occasional school events in Thai KOSENs restricts the total lesson time and place of the additional course in the school timetable.

Another factor to consider is the necessity of exercises in learning AC Circuits as retrieval practices. Karpicke and Blunt (2011) found that retrieval practice is a powerful way to promote meaningful learning of complex concepts commonly found in science education. They showed that retrieval practice produced more long-term learning than elaborative studying, such as concept mapping. Their result contradicted the students' prediction that elaborative concept mapping would produce better long-term learning than retrieval practice. They suggested a possible theory to explain the advantage of retrieval: During retrieval, subjects use retrieval cues to reconstruct what happened in a particular place at a particular time. Roediger III and Butler (2011) also reviewed research that contradicted the traditional view by demonstrating that retrieval practice was a powerful mnemonic enhancer, often producing large gains in long-term retention relative to repeated studying. Oakley and Schewe (2021) explain the effectiveness of retrieval practices from a neuroscience perspective and recommend using repeated retrieval more broadly in teaching practice. They claim, 'At the heart of active learning lies something called "retrieval practice." In other words, you want to see if you can pull information from your own memory, or work with it in your mind, rather than simply looking at the material. The more you retrieve the material, and the broader the set of contexts you *retrieve* the materials in, the stronger and more broadly connected the neural links become. Oddly enough, the best way to put information into your long-term memory is to try to *retrieve* it from your own long-time memory instead of just looking at the answer.'

The authors also believe that building the foundation of circuit analysis is hopeless without exercises or the practices to conduct a series of analytical processes that allow students to compose their ideas, make a mathematical model, calculate mathematically, and confirm the appropriateness of the mathematical answer for the engineering problem. Yoshioka, Nishizawa, and Tsukamoto (2001) reported the necessity and the effectiveness of individualized mathematics exercises on KOSEN students' performance. The exercises also improved the students' performance in the following engineering subjects and reduced the number of drop-out students (Nishizawa, Yoshioka, Tsukamoto, and Ozeki, 2003). However, as the time constraints did not allow the extra course to increase the lesson time for incorporating exercises in the face-to-face lessons, we considered employing blended learning for the course to have face-to-face exercises in the limited face-to-face lessons.

Blended learning has evolved significantly, driven by technological advancements and global pedagogical shifts (Ashraf et al., 2021). Initially emerging to overcome the drawbacks of pure online instruction by combining the strengths of face-to-face and online settings, blended learning aimed to enhance learning engagement and provide flexible learning experiences beyond simple online content repositories. Lalima and Dangwal (2017) discussed the concept of blended learning, its main features, and its implementation prerequisites. Means, Toyama, Murphy, and Baki (2013) found the performance advantage of blended learning over traditional face-to-face instruction through their meta-analysis of 45 studies. Tayebinik and Puteh (2009) reviewed the benefits of blended learning, including increased communication, engagement through face-to-face communication, a sense of community, collaborative tasks, adequate feedback, active participation, providing help, and a fun and practical manner of teaching and learning, other than improved academic performance. They concluded that blended learning is more favorable than pure e-learning and offers advantages for learners with a sense of community. Kaur (2013) points out the advantage of blended learning as switching from passive to active learning. The focus of the classroom shifts from a presentational format to one of active learning. This involves putting learners in situations that compel them to read, speak, listen, and think. Oliver and Trigwell (2005) evaluate the benefit of blended learning as the shifts in the emphasis from teacher to learner, from content to experience, and from naively conceptualized technologies to pedagogy.

We employed blended learning in the 2024 AY as a modification to the course of the 2023 AY. By moving lectures from face-to-face lessons to on-demand videos, we could use the face-to-face lesson time for paper-based exercises and interactive discussions on the solutions. A possible concern of blended course design was whether we could rely on the students' learning from the on-demand videos before the face-to-face sessions, as the face-to-face sessions did not work without the students' prior work. However, we were optimistic because the target students of this course knew the necessity of the course and were highly motivated to learn AC circuits.

Materials and Methods or Pedagogy

Face-to-face lectures in the 2023 AY

The extra course in the 2023 AY consisted of nine face-to-face lectures on AC circuits, starting with the waveform of AC voltages and currents, phasor representations of the waves and impedances using complex numbers, and circuit analyses using phasors and impedances (Table 1).

Table 1 Contents of the extra course

Week	Contents
1	Radian, sine and cosine waves
2	AC voltage, inductive and capacitive circuits
3	Calculation of complex numbers
4	Phasors with complex numbers
5	Impedance and admittance
6	Series and parallel AC circuits
7	AC circuit analysis methods
8	AC power
9	Resonant circuits

As the extra course covered more extensive content than the 15 100-minute lessons in the regular course in KOSEN-KMITL, its 60-minute lectures must be packed with denser knowledge than the regular lessons. The course included radian and sinusoidal waves in week 1 and calculating complex numbers in week 3, because the contents were not taught as profoundly as the method to be used in AC circuit analysis in the regular mathematics courses. Other prior knowledge, such as algebra, trigonometric functions, and calculus, is covered well in regular classes.

Teaching materials (PowerPoint files) were also packed with Japanese and English explanations, as learning Japanese terminologies and expressions used in the Engineering context was one of the course's purposes. On the other hand, the lectures were conducted in English to facilitate an easier understanding of the new concepts and ideas.

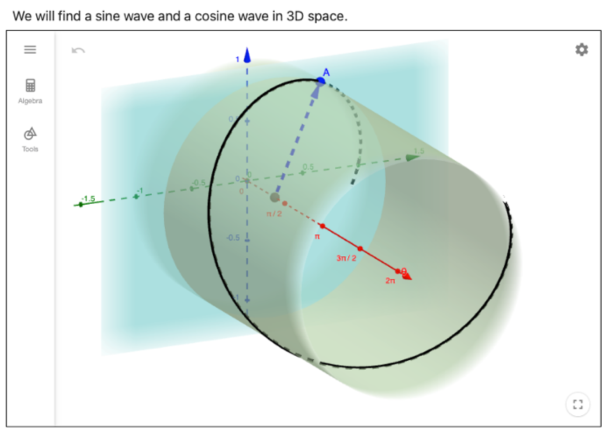
Table 2 Video clips and interactive GeoGebra contents

Week	Video clips	GeoGebra contents
1	6	6
2	3	3
3	4	1
4	4	3
5	4	0
6	5	0
7	5	0
8	5	1
9	4	0

Six ME and nine Computer Engineering (CE) students joined the course. They were expected to tackle the exercises after the lessons by themselves. The materials were all new to the ME students, but for the CE students overlapped with ones as they simultaneously learn AC circuits in their regular course. The lectures were recorded, edited into several short video clips, and uploaded to the server for the students to review the contents after the lessons (Table 2).

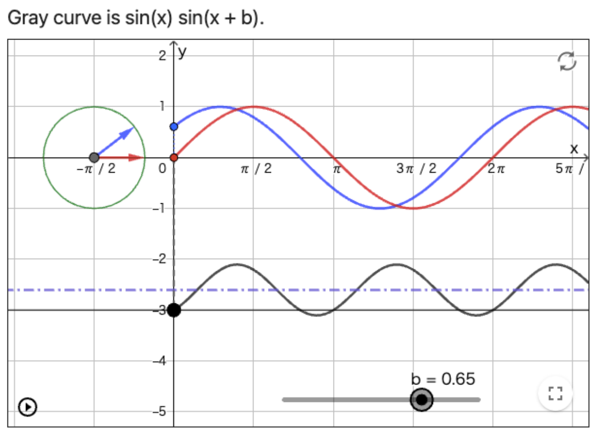
The teaching materials included interactive GeoGebra content (Figs. 1 and 2) to visualize mathematical models. GeoGebra (2025) is a free mathematics software tool widely used to create visual, interactive content. Kllogjeri (2017) argues that visualization is expected to teach the students the ‘feel’ (teach them how to have an eye or sense how to get from ‘here’ to ‘there’). The learning strategy assisted by the mathematics software tool allowed students to better understand abstract content with symbolic expressions through computer visualization with interactive and dynamic graphical representation. Individual work with the content helped low-performing students catch up with their classmates (Werachai & Nishizawa, 2024).

Visualization is especially effective in introductions. For example, a helix in three-dimensional (3D) space can visualize the relation between a sinusoidal wave, which is the shadow of the helix to the x(red)-z(blue) vertical plain in Fig. 1, and a circle, which is the shadow to the other y(green)-z(blue) vertical plain. The animation of a moving point on the helix is a convincing demonstration of the relationship. Leaners confirm the relationship by rotating the helix in the 3D space in this content and observing that the same helix looks like a sine wave, a cosine wave, or a circle when they look at it from different viewpoints. Students’ understanding of the relationship is important because it explains why we can use phasors as the representatives of AC waves.



(https://www.geogebra.org/m/z5nr7rnq)
Fig. 1 An interactive GeoGebra content for showing the connection between a phasor and a sinusoidal wave

Fig. 2 is another example that visualizes the relationship between the phase difference of a voltage $v(t)$ and a current $i(t)$, with the power $p(t) = v(t) \cdot i(t)$, which is the multiplication of the two functions. When the amplitudes of the voltage and the current are the same, the amplitude of the power wave stays the same. However, the average power, the central horizontal line of the power wave, changes with the phase difference of the voltage and the current, expressed by the parameter b in Fig. 2. Learners can confirm the relation by shifting the value of phase difference b using the slider in the content. Learning from this content before the face-to-face lesson is especially valuable because the complex power uses the fact that the average and amplitude of active power, where the contributed voltage and current are in phase, are always the same. Students can ask questions better after learning the relation before the face-to-face lesson.



(https://www.geogebra.org/m/t2y5qrgr)
Fig. 2 An interactive GeoGebra content for showing the change of AC power as a wave

Blended course in 2024 AY

The course consisted of the students' prior learning from the on-demand video lectures on AC circuits (Fig. 3) and interactive GeoGebra content (Figs. 1 and 2), combined with nine face-to-face exercises in the 2024 AY. Nine-hour lectures were divided into 40 video clips shown in Table 2. It is a typical structure of Flipped Classrooms (Delozier & Rhodes, 2017), and its primary purpose is to use every face-to-face lesson for the students' activities in the exercises and discussion.

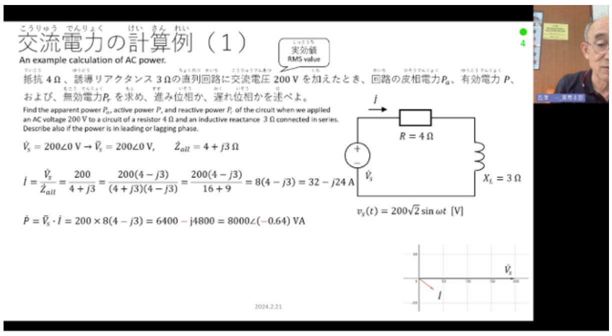


Fig. 3 A snapshot of a lecture video for week eight

The lecture videos recorded in the previous year and teaching materials, including interactive GeoGebra content, were placed on the servers and used as the students' independent learning two weeks before the face-to-face exercises. The students access the online content from their notebook PCs or tablets through the Wi-Fi in the students' dormitories at any time, including weekends. Although visualization, helped by the GeoGebra content, is a powerful method for understanding mathematical models, the time to utilize it comfortably varies from student to student. In that sense, the interactive content might be better used in independent learning than in time-restricted face-to-face lessons. The students tackled the paper-based exercises (Fig. 4), compared their solutions with the example solutions, and discussed their appropriateness with each other in the face-to-face sessions. The exercises were the main activities used in the EE department's regular AC circuits courses in KOSEN-KMITL (KOSEN-KMITL, 2025b). However, the language used in the exercise papers was different. When the exercise papers for transfer students were uploaded to the server with the other learning content, they contained only Japanese sentences. However, additional English texts were added at the face-to-face sessions. The instructor tried to use Japanese as much as possible in the face-to-face sessions to enhance the students' learning of Japanese terminologies and expressions in the 2024 AY. After the exercise sessions, the students were asked to submit their solutions to the file server.

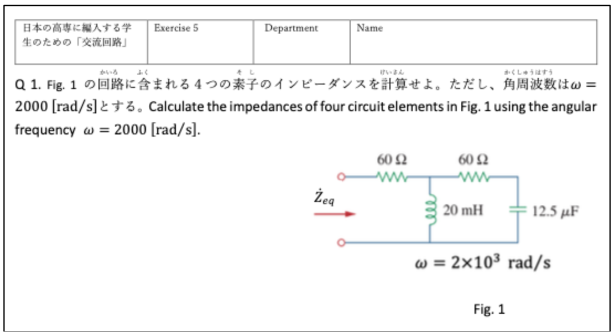


Fig. 4 An example of the exercise sheets

Six ME students were the regular students expected to join the face-to-face exercise sessions, as they did not learn AC circuits in regular courses. Eight Electrical & Electronics (EE) and eight CE students were invited to tackle the exercise problems in the face-to-face sessions. However, for EE and CE students, the extra course was an elective activity, as they were learning AC circuits in their regular classes.

Results and Discussion

Face-to-face lectures in the 2023 AY

All six ME students joined the course, but only three of the nine CE students attended it regularly. The other CE students did not come to the lessons, possibly because the content overlapped with their regular course on AC circuits. The necessity of the course must be reconsidered for the CE students.

According to the questionnaire conducted in August 2024 after the students had transferred to Japanese KOSENs and spent the first semester there, all the students who had regularly attended the course agreed that 'the course was beneficial for the classes in Japan' and 'the class is necessary for juniors who will be transferred to Japan.' However, almost half (44%) of all the transferred students declared they had been too busy to take extra courses before the transfer. It explains why some of the CE students did not join the course.

We could not effectively use interactive GeoGebra content during the lecture because of the limited lesson time. Although the teacher demonstrated the content to introduce new ideas quickly, the students had little time to manipulate it during the lessons. The content was meant to be used by students to confirm the relationship by manipulating the objects themselves, and its impact in the quick demonstration must be weaker.

Overall, we felt the necessity to redesign the course in the next year: who should join it, how to conduct the course, and how to use the restricted time of the face-to-face lessons.

Blended course in the 2024 AY

The redesigned course adopted blended learning, which combined the students' prior individual learning from the on-demand video lectures and interactive GeoGebra content with the following face-to-face exercise sessions. According to the record on the video server, the ME students viewed all video clips for the first four weeks, but the ratio dropped to less than half in the last three weeks (Table 3). We had no means to check how the students used GeoGebra content.

Table 3 Video views

Week	Views
1	100%
2	100%
3	100%
4	100%
5	67%
6	94%
7	17%
8	48%
9	44%

The instructor recognized that the students had little difficulty tackling the exercise problems until week six, the questions they asked hit the mark, and their discussions in the face-to-face sessions were valuable. The students were well prepared to join the face-to-face exercise sessions, and we could presume that the video clips and the other learning content helped them. On the other hand, they seemed to have some difficulties in the latter three weeks.

We should consider reducing the content of the last three weeks, which cover some technical analyses of AC circuits, AC power, and resonant phenomena (Table 1). These contents may be a little advanced for the first course of AC circuits, and the students' workload for the concurrent regular lessons is also increasing as the final examination of the second semester approaches in late February.

The ME students attended 93% of the face-to-face sessions and submitted 98% of the exercise papers after the sessions (Table 4). The CE students did not join the exercise sessions, but four out of eight submitted solutions to the problems. Their diverse attendance may be deeply affected by their learning of AC circuits in the regular courses and the vague sense of necessity, whether the knowledge of AC circuits is necessary for their further study in Japan. The EE students selected topics to join the exercise sessions, and five out of eight students submitted the exercise papers. They used this course strategically to compensate for the knowledge they learned in the regular course.

Table 4 Attendance at the face-to-face sessions and submission of exercise papers

Department (N of students)	Attendance to the face-to-face sessions	Submission of exercise papers
ME (6)	93%	98%
CE (8)	0%	60%
EE (8)	40%	69%

After the course but before the transfer, five out of six ME students answered the questionnaire. They said they preferred the face-to-face exercise sessions to the face-to-face lectures they did not receive. The support from the students may come from the student-centered activity during the face-to-face lessons (McLaughlin et al., 2014).

By adopting blended learning, we could include exercises in the face-to-face sessions of the extra course on AC circuits for transfer students. The submitted exercise papers showed that the ME students understood the basics of AC circuit analysis at the same level as the EE and CE students, who learned AC circuits in their regular courses. Blended learning also reduced the preparation efforts of the faculty because they could recycle the lecture videos recorded and edited in the former year, and other inherited teaching material.

On the other hand, we could not know whether the interactive GeoGebra content, which is uploaded to the server for the students' prior learning before the face-to-face exercise sessions, helped the ME students learn effectively in this study.

We also need to confirm if the blended course helped the transferred students to learn well in Japanese KOSENs by tracking their learning histories after the transfer.

Conclusions

Blended learning was used to redesign an extra course on AC circuits for transfer students from Thai-KOSEN to Japanese KOSENs in the 2024 AY. The course in the prior year could not include exercises, which were an essential part of learning AC circuits deeply, because of the time constraint. The blended learning method allowed the course to combine on-demand video lectures and individual prior work of the students with face-to-face exercise sessions. The blended course worked well for the students who needed to learn the first course of AC circuits analysis, which might become a serious curriculum gap at the transfer. In the questionnaire, the students also evaluated exercises higher than lectures as face-to-face learning activities. Although we still need to adjust the content for the extra course, it will continue to support transfer students from Thai-KOSEN to Japanese KOSENs. The highly motivated students supported the success of the course.

References

Ashraf, M. A., Yang, M., Zhang, Y., Denden, M., Tlili, A., Liu, J., Huang, R., & Burgos, D. (2021). A Systematic Review of Systematic Reviews on Blended Learning: Trends, Gaps and Future Directions. *Psychology research and behavior management*, *14*, 1525–1541. https://doi.org/10.2147/PRBM.S331741.

Delozier, S. J., & Rhodes, M. G. (2017). Flipped Classrooms: A Review of Key Ideas and Recommendations for Practice. *Educational Psychology Review*, 29. 141-151.

GeoGebra (2025). Accessed from https://www.geogebra.org

Karpicke, J. D., & Blunt, J. R. (2011). Blended learning Retrieval Practice Produces More Learning than Elaborative Studying with Concept Mapping. *Science*, 331(6018), 772–775. DOI: 10.1126/science.1199327.

Kaur, M. (2013). Blended learning – its challenges and future. *3rd World Conference on Learning, Teaching and Educational Leadership*.

Kllogjeri, P. (2017). *GeoGebra in Teaching and Learning Mathematics in Secondary Schools*, LAP LAMBERT Academic Publishing, p.60.

KOSEN-KMITL (2025a). Curriculum of the Mechatronics Engineering program. Retrieved from http://www.kosen.kmitl.ac.th/en/curriculums/diploma-of-engineering-in-mechatronics-engineering-en

KOSEN-KMITL (2025b). Syllabus of '03005090 Electrical Circuit 2', Electrical and Electronics Department. Retrieved from https://drive.google.com/drive/folders/1XTfT7rSdEm2zPZDkVUNo19B19fW-C3Yj

Lalima, & Dangwal K. L. (2017). Blended Learning: An Innovative Approach. *Universal Journal of Educational Research*, 5(1), 129-136.

McLaughlin, J. E., Roth, M. T., Glatt, D. M., Gharkholonarehe, N., Davidson, C. A., Griffin, L. M., & Mumper, R. J. (2014). The flipped classroom: a course redesign to foster learning and engagement in a health professions school. Academic Medicine, 89, 236–243.

Means, B., Toyama, Y., Murphy, R., & Baki, M. (2013). The effectiveness of online and blended learning: A meta-analysis of the empirical literature. *Teachers College Record*, 115(3) 1–47.

Nishizawa, H., Yoshioka, T., Tsukamoto, T., & Ozeki, O. (2003). Education of Fundamental Mathematics with Individualized Exercises. *KOSEN Kyouiku* (in Japanese), 24, 211-216.

NIT (2025). Syllabus of 'Electric Circuit IIA', NIT Akashi College, Electrical and Computer Engineering. Retrieved from https://syllabus.kosen-k.go.jp/Pages/PublicSyllabus?school_id=27&department_id=12&subject_code=7226&year=2024&lang=en

Oakley, B., & Schewe, O. (2021). *Learn Like a Pro, Science-Based Tools to Become Better at Anything,* 27.

Oliver, M., & Trigwell, K. (2005). Can 'Blended Learning' Be Redeemed? E-Learning, 2(1), 17-26.

Roger III, H. L., & Butler, A. C. (2011). The critical role of retrieval practice in long-term retention. *Trends in Cognitive Sciences*, 15(1), 20-27.

Tayebinik, M., & Puteh, M. (2012). Blended Learning or E-learning? *International Magazine on Advances in Computer Science and Telecommunications* (IMACST), 3(1), 103-110.

Werachai, P., & Nishizawa, H. (2024). Impact on Student Learning Outcomes in Mathematics Using GeoGebra. *Proc. of the 29th Asian Technology Conference in Mathematics.* Retrieved from https://atcm.mathandtech.org/EP2024/regular/22164.pdf

Yoshioka, T., Nishizawa, H., & Tsukamoto, T. (2001). Method and Effectiveness of an Individualized Exercise of Fundamental Mathematics. *Community College Journal of Research and Practice*, 25, 373–378.