DOI: doi.org/10.58797/cser.030103

Project-Based Learning in Teaching Amplitude Modulation Techniques to Enhance Vocational High School Student Competencies

Nur Laila[a)], Dian Ayu Lailatul Rahmania, Kezya Marisca Eunice Tambunan
Amelia Esa Ripalta, Farizi Afdhal Jatmiko

Department of Physics Education, Faculty of Mathematics and Natural Science, Universitas Negeri Jakarta, Jl. Rawamangun Muka, Jakarta 13220, Indonesia

Email: [a)] nur.laila@mhs.unj.ac.id

Abstract

Amplitude Modulation (AM) is a fundamental concept in analog communication systems and a core topic in vocational electronics education. However, many students struggle to grasp the abstract nature of AM theory when taught through conventional methods. This article presents the development of an innovative instructional model based on Project-Based Learning (PjBL) to support students' understanding of amplitude modulation through hands-on activities. The learning model guides students in constructing and analyzing AM circuits using basic electronic components and simulation tools. The design process emphasizes inquiry, collaboration, and experimentation, enabling students to explore AM signal behavior in practical contexts. The instructional materials include project worksheets, simulation tasks, and performance-based assessment rubrics. This model aims to bridge the gap between theory and practice, foster technical competencies, and enhance student engagement in vocational high schools. The proposed design is ready for further implementation and validation in real classroom environments.

Keywords: amplitude modulation, multisim, project based learning

Received: 4 March 2025
Revised: 15 April 2025
Accepted: 17 April 2025
Published: 24 April 2025
Issued: 30 April 2025

Current Steam and Education Research
e-ISSN: 3025-8529

INTRODUCTION

The rapid development of communication technology has fundamentally transformed how humans access, process, and transmit information (Karanam et al., 2024). This advancement not only impacts industrial and economic sectors but also brings significant implications to the field of education, particularly in electronics and telecommunication engineering (Portillo et al., 2024). One of the essential components of any communication system is modulation techniques, which play a crucial role in transmitting information through various media (Rong & Mitra, 2024). Modulation is the process of altering the characteristics of a carrier wave—such as amplitude, frequency, or phase—based on an information signal. In essence, it enables the transmission of low-frequency signals, which are generally more susceptible to noise, by superimposing them onto high-frequency carrier waves, thereby ensuring more stable and efficient communication.

One of the most basic yet widely used forms of modulation is Amplitude Modulation (AM). In this method, the amplitude of the carrier signal is varied in proportion to the information signal (Xiong et al., 2024). AM is considered a linear modulation technique, meaning that the variation in amplitude directly follows the waveform of the input signal (Saragada & Das, 2024). While modern communication systems often employ more sophisticated methods such as Frequency Modulation (FM) or digital techniques like QAM or PSK, AM continues to be relevant in various analog communication applications, including AM radio broadcasting. Its primary advantage lies in its ability to transmit signals over long distances, although it is less efficient in terms of power usage and signal clarity compared to FM (Altuna et al., 2024).

In the context of vocational education, particularly in Vocational High Schools with expertise in Electronics and Telecommunications, mastering modulation techniques is a fundamental competency (Alphonsus & Schmees, 2024). This knowledge is not only essential theoretically but also practically, as it equips students with the skills required to meet the demands of the communication technology industry (Valencia-Medina et al., 2024). However, current teaching methods in many vocational schools are still dominated by traditional, teacher-centered approaches that emphasize theoretical explanations, often lacking meaningful hands-on learning experiences (Long et al., 2024). This limitation is further exacerbated by a shortage of teaching aids and project-based activities that can foster critical thinking, problem-solving, and collaboration. As a result, students often struggle to connect abstract concepts—such as signal frequency, spectrum, and modulation—with their real-world applications (Safari & Pourrostam, 2024). Thus, there is an urgent need for innovative instructional models that integrate project-based approaches to bridge the gap between theory and practice.

One promising approach to address this issue is Project-Based Learning (PjBL). PjBL positions students as active participants in their learning process by engaging them in meaningful, real-world projects that require them to apply their knowledge to solve problems and create tangible products (Lu & Xie, 2023; Affandy et al., 2024). In the context of teaching amplitude modulation, PjBL can be implemented through projects involving the design and simulation of AM circuits, either via software tools such as Multisim or through actual construction using electronic components (Bauman et al., 2024; González-Sierra et al., 2024). Such hands-on activities not only deepen students' conceptual understanding but also enhance their technical and collaborative skills (Soomro et al., 2024). Furthermore, integrating PjBL in AM instruction creates opportunities for educators to design learning experiences that are contextual, inquiry-based, and aligned with the competencies needed in the 21st-century workplace. These projects challenge students to plan, implement, evaluate, and reflect critically on their learning journey. As a result, PjBL is particularly well-suited to vocational settings, where the development of practical skills and job readiness is a primary educational goal.

Given this background, the present study aims to explore an innovative instructional model for teaching Amplitude Modulation techniques through project-based learning. This innovation is intended to improve students' conceptual comprehension, practical skills, and active engagement in the learning process. It is also expected to contribute to the advancement of teaching practices in vocational education, offering a replicable model for integrating theory with hands-on experience. Ultimately, this research seeks to provide insights and solutions that enhance the quality of communication technology instruction in vocational high schools and better prepare students for the demands of the industry., and prepare students to enter the industrial world with more applicable and relevant skills.

METHOD

This study adopts a developmental research approach focused on the design and implementation of a project-based learning model for teaching Amplitude Modulation (AM) techniques in vocational high schools. The primary objective of this research is to develop an instructional design that integrates theoretical and practical aspects of AM through student-centered, project-based activities. The research does not involve data collection from students, but rather emphasizes the systematic development and refinement of learning tools and strategies. The development process follows the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. Each stage is elaborated as follows:

Analysis Stage

In this stage, a needs analysis was conducted to identify the competencies required in the vocational high school electronics and telecommunications curriculum, particularly regarding modulation techniques. Relevant literature, curriculum standards, and teacher needs were examined to determine the challenges faced in teaching AM and the potential of project-based learning as a solution.

Design Stage

Based on the results of the analysis, a project-based learning model was designed with a focus on amplitude modulation. This included designing learning outcomes, instructional strategies, activity sequences, and project tasks. The learning design emphasized active student participation, problem-solving, and hands-on practice. A prototype of the learning model was outlined, incorporating the creation of an AM circuit as a central project task.

Development Stage

In this stage, the learning materials and tools were developed. These included lesson plans, student worksheets, instructional media (such as circuit diagrams and simulation guides), and an assessment framework tailored to the project-based approach. The AM project was designed to be implementable using both physical components and virtual simulation platforms (e.g., Multisim), allowing flexibility in different classroom environments.

Implementation Stage

https://doi.org/10.58797/cser.030103

While full classroom implementation was not conducted in this study, a preliminary implementation plan was formulated. This plan includes time allocation, group division, resource preparation, and teacher guidance strategies. The goal of this stage was to ensure the feasibility of the learning model and to prepare for future piloting in real classroom settings.

Evaluation Stage

The final stage involved a formative evaluation of the instructional design through expert review and iterative revisions. Feedback was gathered from subject matter experts and vocational school teachers to assess the alignment of the learning model with curricular goals and its potential for classroom implementation. Adjustments were made accordingly to refine the quality and clarity of the learning design.

By focusing on the instructional design process, this study contributes a structured and practical learning model that can serve as a foundation for future experimental studies or classroom implementation. It is expected that the resulting design will provide a meaningful learning experience that enhances students' conceptual understanding and practical skills in amplitude modulation techniques.

RESULTS AND DISCUSSION

The development of a project-based instructional model for teaching Amplitude Modulation (AM) techniques in vocational high schools represents a crucial pedagogical shift toward more contextual, applied, and student-centered learning in the field of electronics and telecommunication education (Tan et al., 2024). In traditional settings, the teaching of modulation—particularly AM—is often heavily theory-driven, with limited opportunities for students to directly experience how these concepts operate in practical contexts. This lack of experiential learning can result in fragmented understanding, where students are able to recite definitions and formulas but struggle to translate that knowledge into real-world applications. By contrast, the instructional design developed in this study attempts to bridge this gap by offering a structured yet flexible learning sequence grounded in Project-Based Learning (PjBL).

The discussion of modulation, especially amplitude modulation, demands a learning approach that can bring abstract concepts into tangible form. Through the process of designing and simulating AM circuits, students are encouraged not only to learn about carrier and modulating signals but also to observe how these signals behave, how they interact, and how modulation can be used in transmission. The learning model supports this by guiding students through authentic tasks that mimic the kind of problem-solving and project execution they are likely to encounter in professional environments. This is especially relevant for vocational students, whose future careers will depend heavily on their ability to apply knowledge rather than simply recall it.

Moreover, this model is informed by sound theoretical underpinnings. Drawing from constructivist learning theory, the model emphasizes knowledge construction through active engagement and discovery. Students are not passive recipients of information but rather active participants in their own learning process. They are challenged to think critically, collaborate with peers, experiment with tools, and communicate their findings—all of which are skills aligned with 21st-century competencies. Furthermore, the design of the AM learning project naturally integrates multiple domains of learning: cognitive (understanding the modulation process), psychomotor (building and testing circuits), and affective (reflecting on the learning process and working in teams). This holistic engagement helps solidify learning and ensures greater knowledge retention.

The inclusion of simulation tools such as Multisim adds another dimension of value to the model. In many vocational schools, access to physical equipment may be limited due to cost or infrastructure constraints (Kett et al., 2024). Simulation software provides an equitable alternative that allows all students to engage in circuit analysis and testing. It also allows students to make mistakes and learn from them in a safe environment, thereby fostering an iterative mindset toward learning (Alsurakji et al., 2024). The ability to test hypotheses, adjust parameters, and observe results in real-time provides immediate feedback that strengthens conceptual understanding. What makes this model particularly promising is its adaptability and relevance to diverse classroom contexts. The modular nature of the activities means that teachers can scale the complexity of the project based on student ability, available time, and institutional resources. The use of a project scenario also encourages students to contextualize their learning, understand its relevance, and develop a sense of ownership over their progress. These characteristics are especially important in vocational education, where learning should be deeply connected to real-life applications and industry expectations.

Although the model has not yet been implemented in a live classroom environment, expert feedback indicates that it is pedagogically robust and practically feasible. Subject matter experts and vocational instructors noted that the sequence of activities, clarity of the project steps, and alignment with curriculum standards make the model suitable for direct integration into existing teaching programs. Some suggested refinements, such as adding more scaffolding for students with low prior knowledge or incorporating diagnostic assessments, were considered and integrated into the final product design. Overall, the developed instructional model stands as a meaningful response to the challenges faced in teaching technical content in vocational education. It offers a pathway to more engaging, effective, and skill-oriented learning that not only conveys knowledge but also cultivates the habits of inquiry, precision, and collaboration that are essential in technical professions. Future research should explore the impact of this model when applied in real classrooms, particularly in terms of its effect on student achievement, engagement, and readiness for work-based learning environments.

CONCLUSION

This study has successfully produced a project-based instructional model tailored for teaching Amplitude Modulation (AM) techniques in vocational high school settings. Developed through the initial stages of the ADDIE framework—Analysis, Design, and Development—the model emphasizes student-centered learning through hands-on, contextualized projects. The learning design integrates core concepts of AM with practical circuit design activities, supported by simulation tools and assessment instruments that encourage active participation, critical thinking, and technical skill-building.

The design process highlights the importance of connecting theory to real-world applications, particularly in vocational education where students are expected to develop both conceptual understanding and practical competencies. By involving students in project-based tasks that mimic authentic professional scenarios, the model promotes deeper engagement, collaborative learning, and experiential knowledge construction. Furthermore, the inclusion of simulation tools ensures accessibility and flexibility, making the model adaptable to diverse school contexts and resource availability

REFERENCES

Affandy, H., Sunarno, W., Suryana, R., & Harjana, H. (2024). Integrating creative pedagogy into problem-based learning: The effects on higher order thinking skills in science education. *Thinking Skills and Creativity*, *53*, 101575–101575. https://doi.org/10.1016/j.tsc.2024.101575

Alphonsus, N. S., & Schmees, J. K. (2024). A community for expertise development – South African vocational colleges and their internal and external social characteristics. *Journal of Vocational Education & Training*, *77*(1), 101–120. https://doi.org/10.1080/13636820.2024.2443918

Alsurakji, I. H., El-Qanni, A., Malhis, T., Ahmed, M., Zayed, M., Hmoudah, M., Ahmed, W. H., Najjar, M., Abuabiah, M., & Shaqour, B. (2024). Bridging theory and practice: CFD simulation and interactive VR for conduction heat transfer learning. *Computer Applications in Engineering Education*, *32*(5). https://doi.org/10.1002/cae.22755

Altuna, R., Jung, Y., Petropoulos, P., & Vázquez, C. (2024). Power Over Fiber and Analog Radio Over Fiber Simultaneous Transmission Over Long Distance in Single Mode, Multicore, and Hollow Core Fibers. *Laser & Photonics Review*, *18*(8). https://doi.org/10.1002/lpor.202400157

Bauman, L., Hansen, B., Goodhew, L., & Robertson, A. (2024). Student conceptual resources for understanding electric circuits. *Physical Review Physics Education Research*, *20*(2). https://doi.org/10.1103/physrevphyseducres.20.020128

González-Sierra, J., Trujillo-Franco, L. G., & Abundis-Fong, H. F. (2024). A Jupyter Notebook for teaching mathematical modeling with experiments. *Computer Applications in Engineering Education*, *32*(6). https://doi.org/10.1002/cae.22801

Karanam, S. A., Mani, D., & Saha, R. L. (2024). Growing Technological Relatedness to the ICT Industry and Its Impacts. *Information Systems Research*. https://doi.org/10.1287/isre.2020.0627

Kett, N., Spray, E., Rutherford, N., & Rendoth, T. (2024). Integration of simulation technology with assessment in initial teacher education. *Australasian Journal of Educational Technology*, *40*(4), 155–172. https://doi.org/10.14742/ajet.9450

Long, Y., Zhang, X., & Zeng, X. (2024). Application and effect analysis of virtual reality technology in vocational education practical training. *Education and Information Technologies*. https://doi.org/10.1007/s10639-024-13197-7

Lu, D., & Xie, Y.-N. (2023). The Application of Educational Technology to Develop Problem-solving Skills: A Systematic Review. *Thinking Skills and Creativity*, *51*, 101454. https://doi.org/10.1016/j.tsc.2023.101454

Portillo, F., Soler-Ortiz, M., Sanchez-Cruzado, C., Garcia, R. M., & Novas, N. (2024). The Impact of Flipped Learning and Digital Laboratory in Basic Electronics Coursework. *Computer Applications in Engineering Education*, *33*(1). https://doi.org/10.1002/cae.22810

Rong, B., & Mitra, R. N. (2024). Wireless Communications: From Fundamentals to Beyond 5G, 3rd Edition. *IEEE Wireless Communications*, *31*(3), 14–15. https://doi.org/10.1109/mwc.2024.10558815

Safari, M. M., & Pourrostam, J. (2024). The role of analog signal processing in upcoming telecommunication systems: Concept, challenges, and outlook. *Signal Processing*, *220*, 109446. https://doi.org/10.1016/j.sigpro.2024.109446

Saragada, P. K., & Das, B. P. (2024). Process-Variation-Aware In-Memory Computation With Improved Linearity Using On-Chip Configurable Current-Steering Thermometric DAC. *IEEE Transactions on Circuits and Systems I Regular Papers*, *71*(10), 4586–4596. https://doi.org/10.1109/tcsi.2024.3422883

Soomro, S. A., Nanjappan, V., Casakin, H., & Georgiev, G. V. (2024). Fostering technical skills and creativity in the digital fabrication spaces: an open-ended prototyping approach. *International Journal of Technology and Design Education*. https://doi.org/10.1007/s10798-024-09940-3

Tan, X., Lin, X., & Zhuang, R. (2024). Development and validation of a secondary vocational school students' digital learning competence scale. *Smart Learning Environments*, *11*(1). https://doi.org/10.1186/s40561-024-00325-6

Valencia-Medina, E. M., López-Valencia, S. M., Jaramillo-Mediavilla, K. M., Andrade-Palacios, J. C., & Jaramillo-Mediavilla, S. J. (2024). Integration of ICT in the Attitudes and Knowledge of University Students. *Evolutionary Studies in Imaginative Culture*, 398–406. https://doi.org/10.70082/esiculture.vi.819

Xiong, Q., Zhang, Z., Huang, C., Pu, M., Luo, J., Guo, Y., Ye, J., Pan, W., Ma, X., Yan, L., & Luo, X. (2024). Amplitude-Phase Independently Encoding Space-Division Multiplexed Wireless Communication Using Beamforming Reconfigurable Metasurfaces. *Advanced Optical Materials*, *12*(28). https://doi.org/10.1002/adom.202401181