



Bridging Theory and Practice in STEM: Evaluating the Microwave Communication Module for Secondary School Teachers

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ABSTRACT

BACKGROUND & CONTEXT

In the Kurikulum Standard Sekolah Menengah (KSSM), wave communication is taught in Form 2 Science (sound waves) and Form 1 Computer Science (analog and digital audio). Building on these foundations, the STEM Microwave Communication Module was created to link theory with real-world applications. Using the COMM-u Kit, 23 teachers from 10 schools joined a mentorship program across Selangor, Klang Valley, and Putrajaya.

PURPOSE OR GOAL

Limited STEM knowledge and resources often hinder teachers from delivering wave topics effectively. The STEM Microwave Communication Module is supported by mentoring and exploring electromagnetic wave transmission and reception, building confidence and enabling students to better understand and engage with wave concepts.

APPROACH OR METHODOLOGY

The program comprised two phases: Phase 1 introduced electromagnetic wave theory and the COMM-u Kit, while Phase 2 emphasized hands-on activities through group competitions. Effectiveness was assessed using pre- and post-tests with a Paired T-Test, evaluating teachers' knowledge and teaching skills.

OUTCOMES

Among 23 teachers assessed, 14 improved by over 15%, four by 7%, and two showed no change. Average scores rose from 59.26 to 77.45, while 90% reported greater confidence in teaching wave concepts using the COMM-u Kit.

CONCLUSIONS

The STEM Microwave Communication Module improved teachers' skills and confidence, using the COMM-u Kit to make wave concepts engaging and practical.

KEYWORDS

Microwave technology, STEM hands-on.

Introduction

The STEM (Science, Technology, Engineering, and Mathematics) initiative in Malaysia aims to enhance students' exposure and competence in these areas. This involves transforming teaching and learning approaches to better integrate a range of STEM skills into the national curriculum. A major focus is on improving teacher education, particularly through professional development programs that equip STEM teachers with the knowledge and skills to teach effectively (Mustaza et al., 2021). Teacher quality is a key factor influencing student performance. Research has shown that teachers play a vital role in sparking students' interest in subjects. Holistically, teacher quality encompasses knowledge, skills, and personal attributes, all of which significantly contribute to developing student competencies (Adam, 2019). Traditionally, STEM lessons have relied on tools like PowerPoint slides, videos, and static 3D models. While these methods can be informative, they often feel one-sided and passive, especially for today's students who are more engaged by interactive and hands-on technology (Khalid et al., 2023).

To overcome this, Fung et al. (2022) suggests using more engaging teaching methods such as interactive tools, media, or creative techniques that can make lessons more lively, meaningful, and effective for students. Modern teaching aids, or Teaching and Learning Materials (TLM), particularly those with audio-visual elements, are vital in creating engaging, student-centered learning environments. This aligns with the principles of the 21st Century Learning (PAK21) approach, which emphasizes interactivity, collaboration, and real-world application. In addition, the developed module integrates practical exercises from STEM specialization subjects to enhance students' conceptual understanding, problem-solving skills, and overall engagement (Siong & Wang, 2018).

Integrating engineering concepts into STEM lessons is a promising way to boost student engagement (Jayarajah et al., 2014). Engineering provides a practical context that connects scientific concepts to real-life experiences (Ismail et al., 2024; Yusof et al., 2021). Through the Engineering Design Approach, these concepts can be integrated into subjects with relevant topics. In this study, for instance, a learning module on communication systems introduces students to electromagnetic wave transmission and reception, building on their prior knowledge of wave characteristics and analog/digital audio from lower secondary school.

The module includes hands-on activities where participants build a radio signal transmitter and receiver using a microcontroller known as the COMM- μ Kit. This practical experience promotes critical and creative thinking, enabling teachers to design, assemble, and test communication systems while engaging with real-world technology. In addition, the module incorporates a game-based learning approach, where participants send and decode ASCII codes to form words. This interactive element not only reinforces technical concepts but also creates an engaging and enjoyable learning environment.

Module Development and Process

The microwave communication module was developed to introduce students to fundamental concepts in microwave and communication technology through engaging, hands-on learning. The module integrates instructional content with interactive activities and game-based learning to foster interest and enhance understanding among students. It comprises four main components as tabulated in Table 1. The first, Module 1: Radio Wave Basics, introduces students to the electromagnetic spectrum and the basic characteristics of radio waves. It includes a hands-on activity involving the construction and testing of a Faraday cage to reinforce theoretical knowledge through experimentation. Module 2: Microwave Communication provides an overview of a complete communication system, including the block diagram and various transmission media. To support visual and conceptual learning, an interactive video on the evolution of communication systems is included. Module 3: Microwave

Communication Kit (COMM- μ) introduces students to a custom-developed transmitter and receiver kit that incorporates RF modules and Arduino-based microcontrollers. Students learn the functions of individual components and perform basic transmitter-receiver connections following a structured manual. Lastly, Module 4 features a game-based activity where students transmit and decode ASCII codes to form words, promoting active engagement and reinforcing digital communication concepts in a fun, memorable way.

Validation Process

The module underwent a two-phase validation process comprising a Training of Trainers (ToT) session and a teacher mentoring workshop. The ToT session was held on 25 October 2024 and involved ten selected students from the Department of Electrical, Electronic & Systems Engineering, Faculty of Engineering and Built Environment. These students were trained in both the operation of the COMM- μ Kit and the facilitation of the module's instructional content. The second phase was the Teacher Mentoring Workshop, titled Microwave Communication Module Using COMM- μ Kit, aimed at equipping teachers with the practical skills required to use the COMM- μ Kit effectively in the classroom. The workshop focused on hands-on training for receiving electromagnetic wave signals and guided teachers on integrating the module into their teaching. Additionally, the workshop aimed to evaluate the impact of using a game-based approach in teaching microwave communication concepts.

Instruments research

The instrument was developed to assess teachers' perceptions regarding microwave communication and electromagnetic waves. A pre-test was administered before the program to evaluate their initial understanding of these topics. Following the completion of the program, a post-test was conducted to measure knowledge gains and assess the effectiveness of the intervention. In addition, participants evaluated the program's overall impact through two components: (A) a questionnaire assessing knowledge acquisition, and (B) feedback on their experience and engagement throughout the program.

Table 1: Module and Instruments of Microwave Communication STEM Module

Module	Learning outcome	Instruments
Module 1 Radio Wave Basics	Identify and describe the electromagnetic spectrum and the characteristics of radio waves. Demonstrate understanding of radio wave behaviour through hands-on experiments such as the Faraday cage activity.	Pre-test (4 Questions) Post-test (4 Questions) Impact questionnaire
Module 2 Microwave Communication	Explain the components and function of a basic microwave communication system, including transmitter, receiver, and transmission medium. Analyze the evolution of communication technologies through multimedia and visual resources.	Pre-test (6 Questions) Post-test(6 Questions) Impact questionnaire
Module 3 Microwave Communication (COMM- μ) Kit	Assemble and test a basic microwave transmitter and receiver system using the COMM- μ Kit. Identify the function of each hardware component, including RF modules and Arduino microcontrollers, in a communication system.	Pre-test (4 Questions) Post-test (4 Questions) Impact questionnaire

Module 4	Apply knowledge of binary and ASCII codes in a practical communication task.	• Impact questionnaire
Game-Based Learning Activity (ASCII Code Game)	Enhance teamwork and problem-solving skills through interactive, game-based learning scenarios.	

Thus, this paper focuses on the feedback gathered from the implementation of the teacher mentoring phase. The second phase, a Teacher Mentoring Workshop titled Microwave Communication Module Using COMM- μ Kit, was conducted on 16 November 2024 at the Watan Meeting Room, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia (UKM). The workshop was attended by 23 secondary school teachers specializing in Science, Computer Fundamentals, or Technology Design. It was facilitated by a team of trained student mentors and supported by 10 committee members. The primary objective of the workshop was to enhance teachers' capacity to deliver microwave communication concepts effectively using the developed module and the COMM- μ Kit.

Teachers' Perspective

Demographic

A total of 23 secondary school teachers participated in the workshop with various backgrounds, as shown in Table 2. The majority of participants were women (78%), while men comprised 22%. All respondents identified as Malay. In terms of age distribution, the largest group (44%) was aged between 40–49 years, followed by 30% aged 30–39, 22% aged 20–29, and 4% aged 50–59. Regarding subject expertise, 52% of the teachers taught Reka Bentuk Teknologi, 30% taught Science, and 18% taught Asasi Sains Komputer. This demographic profile provides context for understanding the perspectives shared by teachers during the feedback process.

TABLE 2: Demographics of participants

Background	Description	Total	Percentage (%)
Gender	Men	5	22
	Women	18	78
Race	Malay	23	100
Age	20-29	5	22
	30-39	7	30
	40-49	10	44
	50-59	1	4
Subject taught	Reka Bentuk Teknologi	• 12	• 52
	Sains	• 7	• 30
	Asasi Sains Komputer	• 4	• 18

Pre- and Post-Test Evaluation

The comparison between pre-test and post-test scores reveals a clear improvement in participants' understanding of microwave communication concepts following the workshop, as shown in Table 3. The mean score increased from 58.76 in the pre-test to 78.78 in the post-test, indicating a substantial gain of approximately 20 percentage points. This improvement suggests that the workshop, which combined hands-on training with conceptual instruction, was effective in enhancing teachers' knowledge.

TABLE 3: Pre and Post Test Analysis

	n	Min	Standard deviation	mean	Standard error
Pre-test	23	59.26	14.7	58.76	3.09
Post-test	23	77.45	12.01	78.78	2.62

Results of the paired *t*-test indicated that this difference was statistically significant, with a large effect size: $t(20) = 5.9, p < .001$. The analysis confirms that the observed increase in scores from before ($M = 58.8, SD = 14.2$) to after ($M = 78.3, SD = 12$) the workshop was not due to chance, thus validating the effectiveness of the intervention.

In addition, the reduction in standard deviation from pre- to post-test suggests a narrowing of the performance gap among participants, indicating more consistent understanding across the group. The relatively small standard error further reinforces the reliability of the mean scores.

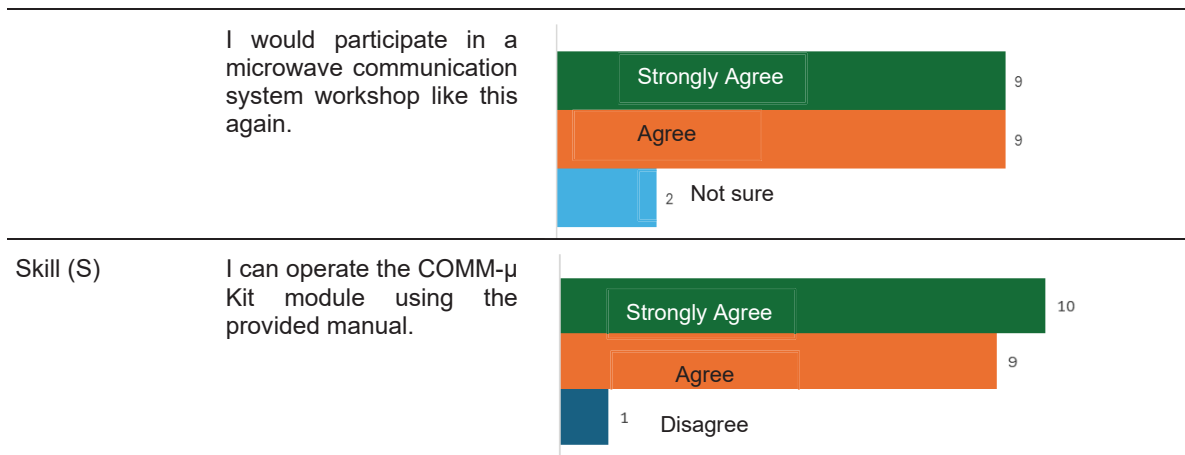
Impact Analysis

This impact analysis consisted of two parts. Part A focused on knowledge enhancement, using 15 questions to assess understanding across three modules: Module 1 Radio Wave Basics, Module 2 Microwave Communication, and Module 3 Microwave Communication Kit (COMM- μ). Of 20 participants, 80% agreed that their knowledge had improved in all modules.

Part B applied the KAS Model (Knowledge, Attitudes, and Skills), which is widely used in education, training, and competency development to measure not only knowledge and attitudes but also technical skills. For Knowledge, in addition to Part A's assessment of basic understanding, this section also evaluated teachers' comprehension of confidentiality in communication. For Attitudes, three questions examined participants' motivation, enthusiasm to share knowledge, and openness to continued learning opportunities. For Skills, items measured participants' practical abilities in handling and applying the COMM- μ Kit technology.-

TABLE 4: Part B, KAS Framework mapping of questionnaire items and teacher responses

KAS Module	Questionnaire	Teachers Feedback
Knowledge (K)	I am confident in explaining the concept of microwave communication systems to others	Strongly Agree 5
		Agree 13
		Not sure 1
		Disagree 1
Attitudes (A)	I am excited to learn more about microwave communication systems.	Strongly Agree 11
		Agree 9
	I am excited to share my experience of attending the COMM- μ Kit Module workshop with others.	Strongly Agree 9
		Agree 10
		Disagree 1



Part B assessed the overall experience and perceptions of the workshop. The feedback was overwhelmingly positive, as shown in Table 4. All respondents (100%) expressed enthusiasm about learning more about microwave communication systems, with 55% strongly agreeing and 45% agreeing. Additionally, 95% of participants indicated a willingness to share their workshop experience with others, while only one participant disagreed. In terms of confidence in explaining microwave communication concepts, 90% of respondents either agreed or strongly agreed, with only two respondents unsure or in disagreement. Furthermore, 95% of participants felt capable of operating the COMM-μ Kit using the provided manual. Interest in future participation was also strong, with 90% expressing willingness to attend similar workshops, and two participants indicating uncertainty.

Conclusion

The implementation of the microwave communication module, together with the COMM-μ Kit, has shown encouraging outcomes in supporting teachers to better understand and teach this complex topic. Through a structured two-phase process starting with the Training of Trainers (ToT) and followed by a Teacher Mentoring Workshop, the program successfully equipped both student facilitators and secondary school teachers with the knowledge and skills needed to deliver the module confidently.

Results from the pre- and post-tests clearly showed an increase in understanding, with a significant improvement in scores after the workshop. This indicates that the hands-on, activity-based approach was effective in enhancing teachers' knowledge. Feedback from the 20 participating teachers also reflected this success. Most of them felt excited to learn more, confident in using the kit, and eager to share their experiences with others. Many also expressed interest in attending similar workshops in the future.

In summary, the program not only improved content knowledge but also created a positive and engaging learning environment. The use of interactive tools and games made the learning process more accessible and enjoyable. These results suggest that this module has strong potential to be used more widely, especially in helping teachers bring STEM topics like microwave communication to life in the classroom.

References

- Adam, A. (2019). Faktor Keberkesanan Guru Cemerlang Sains Dalam Proses Pengajaran dan Pemudahcaraan. *National Conference of Educational Research*: 1-30. <https://www.researchgate.net/publication/335909143>
- Fung, C. H., Poon, K. K., & Ng, S. P. (2022). Fostering student teachers' 21st century skills by using flipped learning by teaching in STEM education. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(12), em2204. <https://doi.org/10.29333/ejmste/12728>

- Ismail, M., Kob, C. G. C., Abdullah, N., & Zamzuri, F. K. (2024). Perspektif Guru Terhadap Elemen Multimedia di Dalam Modul Sequin Topik Reka Bentuk Fesyen Pada Mata Pelajaran Reka Bentuk dan Teknologi Tingkatan Satu: The Teacher's Perspective on Multimedia Elements in the Sequin Module on the Topic of Fashion Design in the First Form Design and Technology Subject. *Asian Pendidikan*, 4(1), 43-52. <https://doi.org/10.53797/aspen.v4i1.5.2024>
- Jayarajah, K., Saat, R. M., & Rauf, R. A. A. (2014). A review of science, technology, engineering & mathematics (STEM) education research from 1999–2013: A Malaysian perspective. *Eurasia Journal of Mathematics, Science and Technology Education*, 10(3), 155-163. <https://doi.org/10.12973/eurasia.2014.1072a>
- Khalid, N., Othman, N., Kasbun, R., & Alimin, S. R. (2023). Penerapan Konsep Gamifikasi Pada Perancangan Modul Pembelajaran Untuk Pendidikan Statistik. *e-Jurnal Penyelidikan dan Inovasi*, 10(2), 85-103. <https://doi.org/10.53840/ejpi.v10i2.139>
- Mustaza, S. M., Yahya, I., Ibrahim, M. F., & Ahmad, A. H. (2021). Program Pementoran STEM di Kalangan Pelajar Prasiswazah Bagi Pertandingan Robotik MakeX. *ASEAN Journal of Teaching & Learning in Higher Education*, 13(1): 124-134. <https://doi.org/10.17576/ajtlhe.1301.2021.08>
- Raflee, S. S. M., & Halim, L. (2021). The Effectiveness of Critical Thinking in Improving Skills in KBAT Problem Solving: Keberkesanan Pemikiran Kritis dalam Meningkatkan Kemahiran dalam Penyelesaian Masalah KBAT. *Jurnal Pendidikan Sains dan Matematik Malaysia*, 11(1), 60-76. <https://doi.org/10.37134/jpsmm.vol11.1.6.2021>
- Siong, W. W., & Osman, K. (2018). Pembelajaran berasaskan permainan dalam pendidikan STEM dan penguasaan kemahiran abad ke-21. Politeknik & Kolej Komuniti *Journal of Social Sciences and Humanities*, 3(1), 121-135. <https://app.mypolycc.edu.my/journal/PMJSSH/article/view/153/100>
- Yusof, Y. M., Ayob, A., & Saad, M. H. M. (2021). Penggunaan Teknologi Kejuruteraan dalam Pendidikan STEM Bersepadu. *Jurnal Kejuruteraan*, 33(1), 1-11. [https://doi.org/10.17576/jkukm-2020-33\(1\)-01](https://doi.org/10.17576/jkukm-2020-33(1)-01)

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