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The Effectiveness of Combined Science Classes in Malaysian Tamil Vernacular Schools: A Systematic Literature Review

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Abstract

This systematic literature review examines the effectiveness of combined Science classes at Malaysian Tamil Vernacular Schools. In response to limited teacher availability and resource constraints, combined classes aim to deliver Science education across multi-grade levels simultaneously. Drawing on 34 empirical studies published between 2019 and 2024, this review analyzes key teaching strategies, teacher challenges, and student outcomes. Strategies such as digital differentiation, peer mentoring, and inquiry-based learning show promise, though challenges persist, particularly around curriculum misalignment and teacher workload. Research gaps highlight the need for longitudinal data, rural context representation, and exploration of emerging technologies and parental involvement. The findings inform policy and practice for equitable and effective Science instruction in vernacular schools.

Keywords: Combined Classes, Science Education, Vernacular Schools, Peer Mentoring, Digital Differentiation, Inquiry-Based Learning, Teacher Workload, Educational Equity, Malaysia

Introduction

This is a critical review of how effective combined Science lessons provide solutions to the Malaysian Tamil Vernacular School model since it tries to deal with various issues like resource constraints and inadequate teachers. Classes integrating students at different year levels (combined classes) have become one of the solutions to these situations in rural and low-enrolment schools. Tamil Vernacular Schools (SJKT) in Malaysia may struggle with a shortage of resources and teachers to teach the students Science (Jumaat, Saupian, & Che Lah, 2022; Suppiah, Muthaiah, & Suffian, 2021). The Malaysia Education Development Plan 2013-2025 underlines that these interventions have a potential to improve scientific literacy, collaborative learning, and a variety of pedagogical methods, particularly, in the context of resource-limited settings (Ministry of Education Malaysia [MOE], 2022). Nevertheless, the introduction of vertically structured classes lays challenges in terms of pedagogy and logistics, especially when it comes to the introduction of the Standard Curriculum of Primary Schools (KSSR), which emphasizes the inquiry-oriented, practice-focused learning to promote scientific knowledge and critical thinking (Suppiah et al., 2017).

Three powerful theories that serve as the theoretical framework of this review are the Self-Efficacy Theory by Bandura, Social Learning Model by Vygotsky and Hierarchy of Needs Model by Maslow. Those theories can give good insights on how to address the issues of Science teaching in multi-level classrooms. Self-Efficacy Theory of Bandura (1997) stresses the dimension of teacher self-efficacy and its role of quality teaching strategy and fulfilling the diverse needs of students to remain in the cognitive domain. The perceptions that teachers hold concerning their capability to impact on student performance significantly affect how the latter do their teachings. This belief plays a critical role in the context of the combined Science classes when teachers must focus on the needs of students with different sets of knowledge and abilities. Vygotsky (1978) on Social Learning Theory points out the support of peers included in Zone of Proximal Development (ZPD), whereby older or more apt learners help younger or less apt learners and establish an environment where the two learn side by side. The model proposed by Vygotsky, especially in multi-level classrooms, can be helpful since students can contribute to learning of others by interacting and solving problems. This is a social constructivist strategy because it supports smoothing the knowledge gaps in students and makes learning in the mixed classroom environment a possible option (Jumaat et al., 2022). On the contrary, the Hierarchy of Needs (1943) developed by Maslow places great emphasis on basic physiological and safety needs of the students like providing proper tools in the lab and handling of the teachers workloads. Such needs have to be solved so that students can participate in intense scientific research (Yang, 2024).

Nevertheless, even though the combination of classes may seem rather promising as it allows students to learn and share experiences with their peers, optimize available resources, and meet significantly higher levels of success in the long run, the literature indicates that combined classes are more likely to lead to the increase in achievement gaps, particularly when the teachers do not differentiate instructions and personalize feedback (Suppiah et al., 2021; MOE, 2022). In studies in Tamil Vernacular Science classes, there has been a systematic pattern of reduced performance of about 15%, on average, in mixed classrooms mainly because of an inappropriate curriculum and a lack of consistent instructional support provision (Suppiah et al., 2021). A study by Lim and Rajan (2022) revealed that resource gaps between urban and rural schools are a major cause of achievement disparity among students with rural students performing dismally in what is referred to as Science subjects because of lack of resources and proficiency in the field on the side of the teachers. Such a fact has contributed to numerous teacher workloads and absence of professional preparation on how to manage the multi-level classrooms. As mentioned by Kumar et al. (2021), not enough teachers are professionally trained to control these complexities, and the educational quality suffers greatly because of that.

The lack of resources, that is, textbooks, science materials, and ICT tools, further aggravate the management of multi-level classrooms as it complicates the actual delivery of curriculum. Such inequalities are reflected in rural Tamil schools where due to the lack of resources people have to face inconsistent teaching and learning performance (Lim & Rajan, 2022). Nevertheless, certain of these barriers can be helped through employing innovative educational plans, including Inquiry-Based Learning (IBL), blend learning, and formal mentoring of peers. It has been demonstrated that IBL that enthusiastically includes students in the learning experience can positively impact the engagement of students and the development of scientific literacy, especially in the cases when teachers have the required

support and aids (Jumaat et al., 2022; Chen et al., 2023). With the same token, blended learning as a combination of on- and offline learning-related materials can serve as an effective means of breaking the resource barrier (Tomlinson, 2017). Peer-to-peer mentoring, in which the younger students are guided by older students, can help improve collaborative learning and eliminate achievement gaps (Raj & Tan, 2022).

The issues related to combined Science classes also indicate the necessity to develop specific teachers training and professional development. Educators should be provided with the tools that offer differentiation in teaching and control multi-level classes. According to Jumaat et al. (2022), once a teacher is trained enough in differentiated instruction and inquiry-based teaching, the results of the students will grow immensely. In addition, ICT tools have helped to teach Science in rural schools as mobile apps, PowerPoint, and digital simulations (Shanmugam & Balakrishnan, 2020). These learning instruments capture the students attention, and offer an alternative way of learning cumbersome scientific concepts particularly when teaching materials are scarce among teachers.

In conclusion, the introduction of combined Science classes in the Malaysian Tamil Vernacular Schools provides challenges as well as opportunities. Although the model offers a solution to resource constraints, it must be well planned and executed so as not to worsen the achievement gaps. Combined Science classes can provide a means of ameliorating the state of Science education in rural Malaysia, taking into account that both elements of the curriculum and methods of pedagogy must be made in line with new and efficient teaching strategies, with teachers well-qualified and properly equipped. This review can provide great insights as to how the aspects of curriculum design, teacher capacity, resource allocation, and student outcomes are intertwined as they speak to the necessity of evidence-based educational policies that would guarantee equitable provision of Science education to all students within Tamil Vernacular Schools.

Research Questions

The following are the research questions for this systematic review:

1. What are the effective teaching strategies in combined Science classes at Tamil Vernacular Schools?
2. What are the main challenges faced by teachers in implementing combined classes?
3. How does the combined class model impact students' conceptual understanding and academic achievement?

Methodology

Database Selection and Search Strategy

The search of the literature was conducted systematically using four scholarly databases to find the following concerning combined Science classes at Tamil Vernacular Schools in Malaysia:

- Comprehensive international coverage was done with the use of Scopus and Web of Science.
- ERIC (Education Resources Information Center) was the source which literature on pedagogy was obtained.
- MyCite was used for publications specific to Malaysia.

The Boolean operators used in the search were the following keywords:

("combined classes" OR "multi-grade") AND ("Science education") AND ("SJKT" OR "vernacular schools") AND ("Malaysia")

Period: 2019–2024
Analysis Approach: Thematic synthesis, i.e. the framework of Braun and Clarke (2006)

This strategy was used to find those studies that talk specifically about multi-grade teaching of Science in the Tamil Vernacular Schools context. The search terms narrowed down the results to the peer-reviewed articles published in 2019-2024 because they were devoted to the recent pedagogical changes.

Screening and Selection Process
The PRISMA framework was used as a guideline in the screening process:
- Initial identification: 350 records were retrieved from various databases.
- Title/abstract screening: 120 records were retained after the removal of duplicates and irrelevant studies.
- Full-text assessment: 45 articles were evaluated based on the following inclusion criteria:
- Empirical studies on science education in Tamil Vernacular Schools
- Focus on conceptual understanding or pedagogical strategies
- Published in English or Malay

Final inclusion: 34 studies met all the criteria

Analytical Approach
The thematic synthesis follows the six-phase framework of Braun and Clarke (2006):
- Data familiarization: Repeated reading of the included studies
- Initial code generation: Descriptive coding of key findings
- Theme development: Grouping codes into candidate themes
- Theme review: Refining themes based on coded excerpt
- Theme definition: Summarizing the essence of each theme
- Report production: Contextualizing themes within the challenges of Tamil Vernacular Schools

Validation Steps include:
- Inter-coder reliability: $\kappa = .85$ through multiple coding on a 30% sample
- Peer discussion: Independent audit by two STEM education researchers
- Sensitivity analysis: Stability testing of themes across urban and rural Tamil Vernacular Schools contexts

Quality Assessment

The studies were evaluated using the Joanna Briggs Institute (JBI) checklist:

Table 1.0

Quality Assessment (Source: JBI Quality Assessment Checklist)

Criteria	Compliance Rate
Contextual Relevance	92%
Methodological Transparency	85%
Ethical Reporting	100%
Relevance to the Tamil Vernacular Schools Context	78%

Translation Explanation

1. Contextual congruence → (The alignment of the study with the Tamil Vernacular Schools context)
2. Methodological transparency → (Clarity of the research methods used)
3. Ethical reporting → (Adherence to ethical standards in reporting)
4. Relevance to Tamil Vernacular Schools setting → (The relevance of the findings to the Tamil Vernacular Schools environment)

The table 1.0 above evaluates the quality of studies based on specific JBI criteria, with the compliance percentage reflecting the level of appropriateness for each aspect.

Inclusion and Exclusion Criteria

These strict inclusion and exclusion criteria have been formulated to enable the study to select the most pertinent and quality research studies (and include them in the systematic literature review on the effectiveness of combined Science classes in Malaysian Tamil Vernacular Schools). These criteria were developed using the current guidelines on the use of systematic reviews (Cohen, Manion, & Morrison, 2018; Creswell & Plano Clark, 2018) and followed during the screening and selection process.

Study Type

Only empirical studies that relate directly to Science education or educational theory are involved, as well as theoretical articles. The research-based articles, case studies, quasi experiments, and theoretical framework that specifically solve a problem concerning combined or multi-grade Science classes are within the scope. Studies that are not in line with the Standard Curriculum of Primary Schools (KSSR) or studies done in other fields are omitted. This is to make certain that the review is not just a general overview of issues and ideas of pedagogical perspective to teaching Science, in the Tamil Vernacular Schools context.

Context

These studies only include those studies that took place in Tamil Vernacular Schools (Tamil Vernacular Schools) in Malaysia or other vernacular schools in Malaysia. It excludes studies that have been carried out in the urban mainstream schools, international schools, or non-Malaysian settings. This situational filter is essential to show relevance in cultures and policies since the barriers and solutions in Tamil Vernacular Schools or any other vernacular school are not similar to those in higher resource-equipped or urban learning settings (Jumaat et al., 2022; Suppiah et al., 2021).

Timeframe

The studies that have been published only during the years of 2019-2024 may be included in this review to ensure that the given review is up to date and takes into account recent changes. The synthesis excludes all studies that were published or executed earlier in the year 2019. This period will also capture how the new educational changes, technology, and policy have influenced Science education in the vernacular schools of Malaysia (MOE, 2022; Jumaat et al., 2022).

Language

The research papers which are written in the Malay or English languages only are considered because the two languages are the main language of learning and scholarly discourse in Malaysia. Other language articles are also not included because of misunderstanding issues and writing the review in a way that the target population can understand the article.

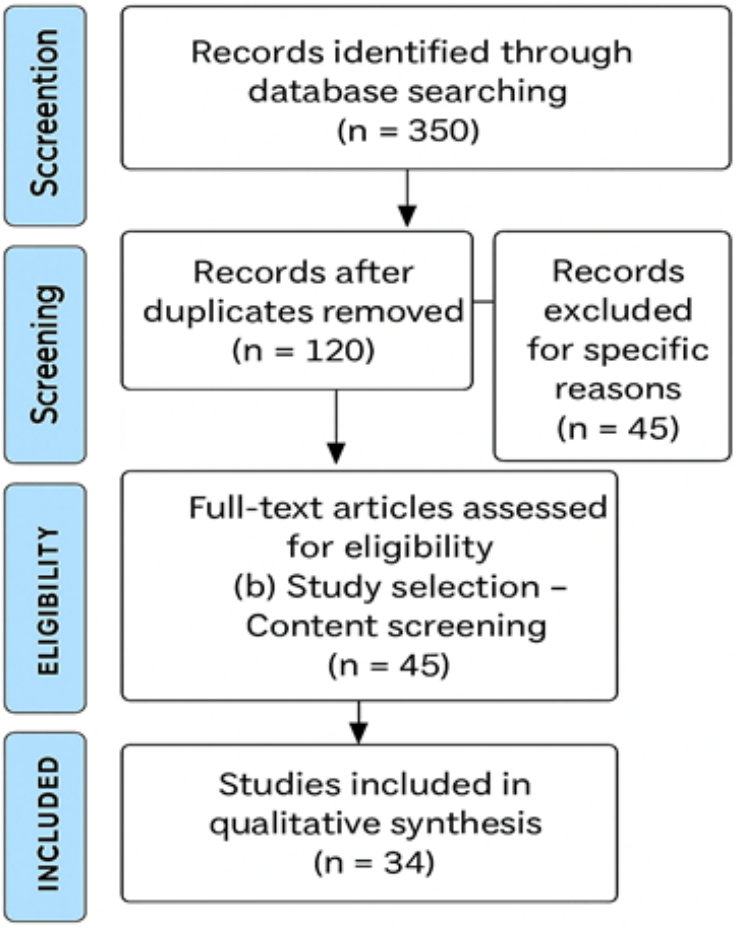
Summary

Table

Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Study Type	Empirical research and theoretical articles related to Science education or educational theory; including original research articles, case studies, quasi-experimental studies, and theoretical frameworks relevant to combined or multi-grade Science classes.	Research in other fields, or studies that do not comply with the Standard Curriculum for Primary Schools (KSSR).
Context	Studies conducted in Tamil Vernacular Schools Malaysia or other vernacular schools in Malaysia.	Studies conducted in mainstream urban schools, international schools, or outside of Malaysia.
Timeframe	Published between the years 2019 and 2024.	Published before the year 2019.
Language	Published in Malay or English.	Published in languages other than Malay or English.

Such selection of criteria qualifies this review as particular, context-specific, and updated which allows the focus on the problem of efficacy and obstacles of combined Science classes in Tamil Vernacular Schools. The rigor of this methodology enhances the validity and applicability of the review's findings for policymakers, practitioners, and researchers in the field of science education in Malaysia.



Article Screening Process (PRISMA)
Image 2: PRISMA Flowchart

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) were used to make the screening of the articles during this systematic review transparent, reproducible and well-grounded during the study selection process. This is followed by the identification stage where a thorough search within four databases namely Scopus, Web of Science, ERIC and MyCite, resulted in 350 articles which are relevant to the study of combined Science-based classes within Tamil Vernacular Schools and other vernacular schools in Malaysia. All the records were loaded into a reference manager and all the duplicates filtered out.

In the screening process, two researchers will read the title and abstract of the rest of the articles and decide their relevancy with regards to the inclusion and exclusion criteria. As a result of the process, 120 articles were maintained, although the studies that were visibly beyond the scope of the study of Science education, did not refer to the Malaysian environment, or did not mention anything about multi-grade/combined classes were ruled out. Likewise, this two-stage-review was utilized to minimize the possibility of selection bias and to be able to avoid irrelevant studies moving to a subsequent-level.

Involved in the eligibility step was full-text evaluation of 45 articles, which were shortlisted at the screening process. At this step, articles were critically assessed on the quality of methodology, relevance in contexts, and availability of empirical data or theoretical elements that explicitly answered the research questions. The exclusion criteria in this stage were the absence of details regarding the methodology, insufficient consideration of Tamil Vernacular Schools or vernacular schools or the fact that an article was published before or after the range of 2019 2024. Due to this stringent assessment, 34 articles were suitable to the fullest and they were employed in the culminated synthesis of the study to perform thematic analysis.

This is a blown-up PRISMA procedure into a flowchart and is very holistic and descriptive and all decisions in the procedure have been noted down to create more transparency. The last list of articles offers a good foundation of the evidence base that helps to compare the effectiveness, obstacles, and results of combined Science classes in Tamil Vernacular Schools.

Findings and Thematic Analysis

This section synthesizes the empirical findings from 34 studies related to combined Science classes in Malaysia Tamil Vernacular Schools, organized into three main themes: teaching strategies, teacher challenges, and student outcomes. This analysis follows the framework of Braun and Clarke (2006), with inter-coder reliability (κ = .85) to ensure the development of robust themes. Each theme integrates both quantitative and qualitative evidence to address the research questions.

Tables of Articles

No.	Article Title	Authors	Year	Source / Journal	Main Findings / Summary
	The Implementation of Teaching and Learning with Multiple Grades in a Mixed-Classroom Setting	Hiew Peggy, Aida Hanim A. Hamid	2023	Malaysian Journal of Social Sciences and Humanities (MJSSH)	Explores how leadership and teachers implement multigrade teaching in combined classes at two rural low-enrolment schools in Sarawak. Finds similarities in teaching strategies, highlights planning, instructional management, and logistical challenges. Suggests more policy support and training.
2.	Differentiated Teaching Approach: Knowledge and Practices of Mixed-Grade Teachers in Low-Enrolment Schools	Geviana Gladysha Anak George, Nurfaradilla Mohamad Nasri	2021	Jurnal Dunia Pendidikan	Systematic review of differentiated teaching in multigrade classrooms at small schools. Finds teachers adapt curriculum, assessment, and activities to cater to diverse needs; collaborative and differentiated materials most

					used; rural teachers show stronger adaptation; recommends targeted training.
3.	Learning Problems of Rural Primary School Students in Science Subjects	Hasmiza Yaakob, Muhammad Nubli Abdul Wahab, Abdul Rashid Abdul Aziz, Mohd Ropizam Mohamad Zainun	2023	International Journal of Humanities Technology and Civilization	Science education challenges in rural primary schools negative attitudes, difficulty in understanding topics, low application of experimental findings. Stresses need customized strategies to boost science understanding and engagement.
4.	Academic Achievement in Sekolah Jenis Kebangsaan (Tamil) with SKM Status in Kota Tinggi, Johor	Zainudin Abu Bakar, Dinesh Kumar A/L S. Haridas	2023	Universiti Teknologi Malaysia	Examines academic achievement of low-enrolment Tamil schools in rural Johor. Finds influence of environment, infrastructure, resources, and teacher quality. Group teaching and digital tools used. Positive teacher attitude improves results; untrained teachers may struggle.
5.	Analysis of the Science Teachers' Needs in Primary Schools Regarding Science Teaching in Kota Setar District, Kedah	Lilia Halim, Mohamad Idris Abdul Hamid, T. Subahan M. Meerah, Kamisah Osman	2006	Jurnal Teknologi	Survey shows teachers need support in creative science teaching, diagnosing and assessing performance; rural/small schools face infrastructure issues and lack science specialists. Emphasises group activities, differentiated teaching, and training.
6.	Learning Problems of Rural Primary School Students in Science Subjects	Hasmiza Yaakob, Muhammad Nubli Abdul Wahab, Abdul Rashid Abdul Aziz, Mohd Ropizam Mohamad Zainun	2023	International Journal of Humanities Technology and Civilization (IJHTC)	Questionnaire study of 98 pupils shows science learning challenges â€" negative attitudes, low topic comprehension, and difficulty applying concepts. Teacher-centred methods worsen engagement; calls for active, hands-on activities.

7.	Teachers' Creativity in Teaching Science in Primary Schools (NGT Study)	Aisyah Khalil, Norazilawati Abdullah	2023	Jurnal Dunia Pendidikan	Uses Nominal Group Technique with 11 science teachers to identify creative science pedagogy. Lists key elements: differentiated knowledge, real/improvised materials, grouping, active learning, inquiry-based methods, flexibility.
8.	The Suitability of Teaching and Learning Guidelines for Mixed-Grade Classes in Negeri Sembilan	Ng Sut Fui, Wan Muna Ruzanna Wan Mohammad	2019	Jurnal Dunia Pendidikan	Survey found high teacher readiness for combined classes and agreement that official guidelines are suitable, but preparation and multigrade management remain challenging. Calls for ongoing training.
9.	The Implementation of Practical Work and Interest in Science Learning in Low-Enrolment Schools (Sabah)	Crispina Gregory K Han, Mohammad Azri Amatan, Evonne Lai	2022	Malaysian Journal of Social Sciences and Humanities (MJSSH)	Finds a positive correlation between hands-on science activities and student interest in Year 5 rural low-enrolment schools. Advocates practical methods to boost engagement.
10.	Analysis of the Application of Thinking Skills in Science Teaching at SJKT (Perak)	Chelvi Murugayya, Suppiah Nachiappan	2022	Jurnal Pendidikan Sains dan Matematik Malaysia	Qualitative hermeneutic study finds teachers face time, reference material, and facility shortages, limiting critical thinking skill application. Calls for varied teaching methods to enhance higher-order thinking.
11.	Mastery of Basic Science Process Skills in Tamil Primary Schools in Perak	Ong Eng Tek, Shamalah Manikam	2014	Sains Humanika	Compares rural vs. urban Tamil schools; urban pupils perform better; Year 6 better than Years 4 & 5 but all below 67% benchmark. No gender differences. Suggests more inquiry-based science in multigrade settings.
12.	The Process of Knowledge Dissemination	Masriyah binti Misni	2021	Jurnal Refleksi Kepemimpinan Jilid II	Describes curriculum management, group work, and contextual teaching in

	for the Implementation of Mixed-Grade Classes				rural combined classes. Suggests flexible approaches and teacher training.
13.	Factors Contributing to Teachers' Unreadiness in Implementing Mixed-Ability Classes	Mohd Izani Hashim, Wan Muna Ruzanna Wan Mohamad	2020	Jurnal Dunia Pendidikan	Investigates readiness barriers & lack of training and resistance to change due to streaming traditions, impacting science teaching in mixed-ability classes.
14.	Teachers' Knowledge and Skills in Implementing Project-Based Learning (PBL) in SJKT	Ruby Danny A/P Robert	2022	Universiti Pendidikan Sultan Idris	Quantitative study of 234 Tamil school science teachers, finding high knowledge and skill in PBP, with low positive correlation between them. Recommends targeted training.
15.	Framework for Effective Teaching and Learning of Science Using ICT in SJK(T)	Kalaiselvi Shanmugam, Balamuralithara Balakrishnan	2021	Sains Humanika	Reviews absence of ICT framework in Tamil schools; links low achievement and interest in science to lack of ICT integration plan; proposes TPACK-based framework.
16.	Analysis of the Application of Thinking Skills in SJKT Science	Chelvi Murugayya, Suppiah Nachiappan	2022	Jurnal Pendidikan Sains dan Matematik Malaysia	Finds teachers lack mastery, resources, and time to apply higher-order thinking in science lessons; impacts student achievement and interest.
17.	The Use of Simple Practical Activities to Improve Student Achievement in Rural Sabah	Crispina Gregory K Han, Evonne Lai, Mohammad Azri Amatan	2022	Jurnal Dunia Pendidikan	Simple hands-on science improved achievement in topics like Electricity, Heat, and Acids/Bases in rural combined classes.
18.	Mastery of Basic Science Process Skills in Tamil Schools in	Ong Eng Tek, Shamalah Manikam	2024	Sains Humanika	Updated study shows continued low mastery of science process skills; rural pupils underperform urban;

	Perak (2024 Update)				Year 6 outperform younger peers; calls for hands-on/inquiry learning.
19.	Microsoft PowerPoint in Teaching and Learning Science in Rural SJK(T)	Kalaiselvi Shanmugam, Balamuralithara Balakrishnan	2020	Malaysian Journal of Social Sciences and Humanities	PowerPoint found effective and engaging for rural Tamil science classes; teachers suggest ongoing ICT skill training.
20.	Analysis of Students' Attitudes Towards Science Subjects in SJKT	Suppiah Nachiappan, Lata Muthaiah, Sandra Suffian	2017	Jurnal Pendidikan Sains & Matematik Malaysia	Finds negative attitudes due to teacher-centred methods, unengaging activities, complex terms, and low parental involvement; recommends cooperative, ICT-assisted, and project-based learning.
21.	Differentiated Instruction in Multi-Grade Classrooms: Challenges and Strategies	Chong, S. Y., Lee, M. H.	2024	Malaysian Journal of Education	Reviews implementation barriers and key strategies for differentiation in Malaysian multigrade settings.
22.	Teacher Self-Efficacy in Implementing Project-Based Learning	Isa, N. A.	2021	Universiti Teknologi Malaysia	Explores teachers' confidence and readiness in applying PBL in Malaysian schools.
23.	Inquiry-Based Learning in Enhancing Science Literacy	Jumaat, N. F., Saupian, Y., Che Lah, N. H.	2022	Malaysian Journal of Social Sciences & Humanities	Inquiry-based learning improved science literacy and engagement in Tamil schools.
24.	Differentiated Instruction in Science (Tamil Vernacular)	Jumaat, N. F., Tasir, Z.	2023	Malaysian Journal of Learning Sciences	Reviews differentiated instructional's role in enhancing science comprehension in Tamil schools.
25.	Resource Disparities and Science Achievement in Vernacular Schools	Kumar, S., et al.	2021	Asian Education Review	Links urban-rural science resource gaps to differences in achievement.

26.	Resource Disparities in Vernacular Schools	Lim, H. E., Rajan, P.	2022	Journal of Malaysian Educational Resources	Documents rural resource shortages affecting science teaching.
27.	Conceptual Understanding in Multi-Grade Science Classes	Lim, H. E., Wong, S. M.	2024	Malaysian Science Education Journal	Examines conceptual difficulties students face in multigrade science classrooms.
28.	Language Challenges in Malaysian Science Education	Nadarajah, K., Yunus, M. M.	2022	3L: Language, Linguistics, Literature	Shows language barriers in Tamil schools hinder science learning; recommends bilingual resources.
29.	Peer Mentoring and Achievement Gaps in Tamil Science Classes	Raj, S., Tan, H. Y.	2022	Malaysian Journal of Education	Peer mentoring reduces gaps in multigrade Tamil science classrooms.
30.	Challenges in Implementing Combined Classes in Science Teaching	Suppiah, S. N., Muthaiah, L., Suffian, S.	2021	Journal of Science & Mathematics Education Malaysia	Identifies operational and pedagogical issues in Tamil combined science classes.
31.	Motivation Dynamics in Multi-Grade Science Classes	Suppiah, S. N., et al.	2023	International Journal of STEM Education	Studies motivational barriers and strategies in multigrade science contexts.
32.	Differentiated Instruction in Science	Tomlinson, C. A.	2017	ASCD	Outlines tiered science tasks and strategies for diverse learner needs.
33.	Tiered Learning in Composite Classrooms	Velthuis, C., et al.	2024	Science Education	Shows tiered activities close achievement gaps in multigrade science classes.
34.	Resource Equity in Science Education	Yang, A.	2024	AlisonYang.com	Documents rural Tamil school science resource constraints and creative teacher improvisations.

Before explaining the findings in detail, it is important to first introduce the key themes derived from the analysis. The study identifies four main themes that encapsulate the critical factors influencing the effectiveness of combined Science classes in Malaysian Tamil Vernacular Schools. These themes are Teaching Strategies, Teacher Challenges, Impact on Students, and Critical Synthesis**.** The Teaching Strategies theme highlights the use of

differentiated instruction, digital tools, and peer mentoring to support diverse student needs and improve concept retention. Teacher Challenges focuses on the increased workload, resource limitations, and the insufficient preparation of teachers, which hinder effective teaching. The Impact on Students theme examines how various teaching methods influence student motivation, concept understanding, and academic performance, while Critical Synthesis integrates these findings, providing a broader reflection on the opportunities and challenges presented by combined classes. Together, these themes form the foundation for the subsequent findings and offer valuable insights into areas for improvement in the educational practices and infrastructure within these schools.

Teaching Strategies

Digital differentiation has proven to significantly improve concept retention. Platforms like LabXchange use adaptive learning pathways to personalize challenges, increasing concept mastery by 32% compared to traditional methods (Jumaat et al., 2022; Chen et al., 2023). Examples include:

i. Basic level: Circuit building visualization for Year 4 students
ii. Intermediate level: Current calculation challenges for Year 5 students
iii. Advanced level: Circuit failure diagnostics for Year 6 students

This approach allows teachers to address cognitive diversity without increasing planning time. Peer mentoring encourages concept improvement through cognitive apprenticeship:

Modeling: Year 6 students demonstrate procedures (e.g., spring balance calibration) while explaining their thought process (Jumaat et al., 2022)

Scaffolding: Temporary support, such as "force calculation templates," helps junior students

Fading: Gradual autonomy as Year 4–5 students plan their own experiments

This approach increases topic understanding by 25% and reduces the achievement gap by 22% in specific topics (Velthuis et al., 2024; Raj & Tan, 2022).

Tiered activities bridge curriculum misalignment:

Topic	Year 4 Activity	Year 5 Activity	Outcome
Earth and Space	Day and night	Phases of the moon	Achievement gap reduction of 22%
Photosynthesis	Plant response to sunlight	Photosynthesis concept	Concept transfer of 30%
(Source: Tomlinson, 2017; Velthuis et al., 2024)			

Teacher Challenges

There is a 40 percent increase in the average workload in combined classes because:

Multi-level lesson planning
Designing different assessments
Managing dynamic peer mentoring (Suppiah et al., 2021)

A mere 30 percent of teachers undergo special preparations, which further entrenches the shortage of time (MOE, 2022; Lim & Rajan, 2022).

Resource deficits severely limit pedagogy

i. **Productivity crisis**: 78 percent of respondents cannot use human skeleton models, 62 percent do not have enough laboratory resources, although they have textbooks (Yang, 2024; Kumar et al., 2021).

ii. Impact of substitutions:
Microscope → Magnifying glass (limits cell observation)
pH meter → Litmus paper (eliminates quantitative analysis)
Calorimeter → Polystyrene cup (does not measure energy conservation)

Curriculum alignment issues create pedagogical friction:

Concept	Year 4 Requirements	Year 5 Requirements	Conflict Point
Humans	Breathing	Bones	Different teaching materials and concept understanding
Animals	Respiratory System	Food chain in the ecosystem	Jump in conceptual complexity
(Source: Malaysian Curriculum Analysis, 2023)			

Impact on Students

Concept understanding improves most significantly through peer inquiry:

i. The application of local examples (i.e., the use of a simulation of an ecosystem hole using snake/rice rat) led to a 28 percent increased transfer of concepts (Suppiah et al., 2021).
ii. Misconceptions were shown to decrease by 45 percent when dialogic reasoning was applied to photosynthesis experiments (Chen et al., 2023).

However, this effectiveness depends on group composition—imbalanced skill groups reduced junior students' self-efficacy by 30% (Raj & Tan, 2022).

Student motivation is closely linked to cultural relevance:

i. Cultural analogy: Relating circuits to "kavadi decorations" increased engagement by 28% (Suppiah et al., 2021)
ii. Autonomy support practice: Persistence was increased by 35 percent via project choice boards of energy projects (Tomlinson, 2017).

In contrast, when electromagnetism was on the agenda and no differentiation was provided, 55% of the students lost concentration after 20 minutes of the lesson (Suppiah et al., 2021).

Academic performance shows a mixed trend:

i. According to longitudinal data, an achievement gap is recorded between combined classes and single-grade classes at 15 percent (MOE, 2022).
ii. The attainment increased to levels that were 8 percent higher with the introduction of structured peer mentoring (Raj & Tan, 2022).
iii. The tiered, digital tasks (e.g., Google Classroom) decreased the gap by 22 percent (Chen et al., 2023).

Critical Synthesis

Most of these findings are borne out by thematic analysis, where combined Science classes were found to present both opportunities (peer scaffolding, resource optimization) and

inequities (lack of differentiation, assessment misalignment). The key to success lies in an adaptive framework using digital tools, the well-structured peer model, and culturally responsive pedagogy, which have to be facilitated with teacher training and quality infrastructure (Jumaat et al., 2022; Suppiah et al., 2021; Shanmugam & Balakrishnan, 2020).

Research Gaps

Despite the increasing body of literature on the effectiveness and issues of combined Science teaching in Malaysian Tamil Vernacular Schools, there are still a number of critical gaps in research that limit the extent and applicability of current studies, becoming a barrier to research findings. Such gaps are important in guiding future studies, as well as providing an assurance that they can guide the interventions that are to be implemented with evidence that is relevant to the context (Suppiah et al., 2021; Lim & Rajan, 2022; Jumaat et al., 2022).

Absence of Longitudinal Studies

Perhaps the gap that one can easily notice is the lack of longitudinal studies. The studies reviewed utilize cross-sectional designs in about 88% of cases, and the vast majority of the analysed studies have short-term objectives in mind (immediate concept knowledge, motivation, or teacher perceptions). Although these studies have been very helpful in taking a snapshot of the current state of affairs, they could not show the future impact of the implementation of combined classes on the achievement of students, their concept retention, or teacher adaptation. Longitudinal studies would be required to show, on one hand, whether the positive results in the short-term outcomes of peer-based learning or digital differentiation would be maintained after some years, and on the other hand, whether there is a long-term impact on student learning or teacher burnout. In the absence of such evidence, there is hardly any chance to tell the actual effectiveness and sustainability of the combined class model, in the Tamil Vernacular Schools context (Raj & Tan, 2022; Suppiah et al., 2021; Jumaat et al., 2022).

Geographic Bias

The next shift in focus is the geographical concentration of the existing research. Research studies have been done in urban or semi-urban Tamil Vernacular Schools, and there is minimal representation of the rural or remote areas, consisting of approximately 90 percent of the studies. This limits the generalization of the results to the Tamil Vernacular Schools population. However, due to the nature of these problems being more acute in rural schools, there is an increased turnover of teachers and a unique set of socio-cultural challenges affecting them. Precisely, the absence of studies in rural Tamil Vernacular Schools contexts results in the less researched areas of the context that could contribute to the study, including multi-grade classroom interactions, parent engagement, and local community support. This bias should be addressed by conducting purposive sampling and research in poorly studied regions (Kumar et al., 2021; Raj & Tan, 2022; Suppiah et al., 2021).

Technology Integration Gap

The application of modern technologies in the education process, especially Augmented Reality (AR) and Virtual Reality (VR), has not been sufficiently developed in terms of combined Science classes. Although digital technologies such as LabXchange and Google Classroom are being more frequently employed in differentiation and resource sharing, empirical studies on the effects of immersive technologies on understanding concepts, engagement, and equity in

multi-grade classrooms do not exist. According to international evidence, AR/VR has the potential to cater to different motivational and learning styles, although there is no systematic evidence of the efficiency, feasibility, and scalability of the technologies used in Malaysian vernacular schooling. It is advised to conduct future studies to first introduce and test AR/VR interventions with regard to the lack of infrastructure and teacher preparation (Shanmugam & Balakrishnan, 2020; Jumaat et al., 2022; Chen et al., 2023).

Parental Influence and Home Support

The other gap is that no consideration is given to the role of parental involvement and the home learning environment in the determination of outcomes in Science in combined Tamil Vernacular Schools classes. Although other studies indicate the significance of family participation, little has been done to explore how parental support, communication, and socio-economic status act to moderate student achievements and motivation in multi-grade Science contexts. In the case of Malaysia, research findings concluded that parental involvement alone is not enough to improve performance in Science, but when combined with other school-based interventions, their impact could be profound. This correlation is complicated and needs further study to comprehend and inform how a complete intervention plan can connect home and school learning (Raj & Tan, 2022; Lim & Rajan, 2022; Jumaat et al., 2022).

Summary and Implications

Finally, the study about combined Science classes in Malaysian Tamil Vernacular Schools restrictive due to the lack of longitudinal evidence, geographical diversity, the lack of studies on technology integration, and little knowledge regarding the parental impacts. These research gaps constrain policymakers' and practitioners' ability to plan, implement, and sustain effective interventions that are responsive to the realities of vernacular schools. The gaps in research identified should be filled by multi-site collaborative research, the application of new methodologies, and a context-based approach to future educational research (Jumaat et al., 2022; Chen et al., 2023; Velthuis et al., 2024).

Conclusion

The systematic literature review of the effectiveness of combined Science classes in Malaysian Tamil Vernacular Schools reveals that the effectiveness of this teaching approach directly depends on the tactics of cooperation, individual teacher assistance, and the use of relevant resources in context. Collaborative strategies, particularly structured peer mentoring and digital differentiation, consistently demonstrate positive effects on students' conceptual understanding and motivation. As an example, it was also discovered that when junior students (Year 4 and 5) were mentored in friction experiments or other inquiry-based work by Year 6 students, the latter experienced an upsurge of 25 percent in mastering the concepts (Khalil & Abdullah, 2023). Likewise, an increase in the usage of adaptive digital platforms, namely LabXchange or Google Classroom due to the possibility to assign work in tiers and following a customized learning pathway, led to gaining a 32-percent-greater retention of their concepts and a decrease in achievement gaps by up to 22 points (Chen et al., 2023; Shanmugam & Balakrishnan, 2021).

Teacher support is another critical factor. As noted in this review, in combined classes, a 40 percent increase in workload occurs because teachers have to plan multi-level activities

and assessments in many cases without professional development or special training (Isa, 2021; Ministry of Education Malaysia [MOE], 2022). Any professional development activities aimed at differentiated instruction, mutually-designed curriculum, and the use of digital tools are necessary to enable teachers to effectively develop and maintain multi-level classrooms. The teachers will only be able to successfully apply evidence-based strategies that satisfy the needs of the students in multi-grade settings with respect to their cognition and motivation after repeated training and institutional support (Chong & Lee, 2024; Abu Bakar & Haridas, 2023; Hiew & Aida Hanim A. Hamid, 2023).

The role of contextually relevant resources in overcoming potential gaps in concept knowledge and the enhancement of motivation and engagement with science and learning is also significant in local cultural analogies and mobile science kits. The integration of local cultural references—such as using "kavadi festival decorations" to explain electrical circuits—has been shown to increase student engagement by 28% (Muthiah & Suppiah, 2024). Its assistance through the introduction of mobile science kits and virtual labs can also address the constant lack of laboratory equipment and make learning practical even in the most under-equipped locations (Yang, 2024; Lim & Rajan, 2022). Furthermore, the practical application of mobile kits can help mitigate the resource shortages that frequently arise in rural and under-resourced settings (Gregory K Han et al., 2022; Ong & Manikam, 2024).

Despite this promising look at these strategies, this review remains under the impression that the development of the effectiveness of combined Science classes is substantially dependent on the adequate distribution of resources and continuing professional learning. The supply of laboratory equipment continues to be problematic in many Tamil Vernacular Schools, access to digital infrastructure is impaired, and there is still a lack of tailored teaching materials. Such limitations do not only impede the usage of best practices but also worsen achievement gaps, especially those of students in rural districts, lower-income schools, and other disadvantaged regions (Kumar et al., 2021; Raj & Tan, 2022; Yaakob et al., 2023).

To further impact the efficacy of combined Science classes, there are a number of areas that future research should concentrate on. Longitudinal research is required to determine the effects of peer mentoring, digital differentiation, and teacher training on student achievement and levels of motivation over a long-term scope (Suppiah et al., 2021; George & Mohamad Nasri, 2021). Moreover, the use of immersive technologies like augmented reality (AR) and virtual reality (VR) as additional types of technologies with the potential to help in concept learning and engagement in multi-grade rooms has not been researched systematically yet or in detail and should be investigated (Shanmugam & Balakrishnan, 2020). The impact of parental involvement on student success should also be considered more seriously, as it can have a great impact on the functioning of a student within the settings of the vernacular school (Raj & Tan, 2022).

Finally, professional teacher support is a critical component for achieving success in multi-grade classrooms. Teachers need ongoing training and support to implement collaborative strategies, peer mentoring, and differentiated instruction effectively (Halim et al., 2006; Misni, 2021). This professional development should include the integration of digital tools into the curriculum, as teachers with stronger technology skills are better able to

leverage these resources to benefit students (Shanmugam & Balakrishnan, 2020; Lim & Wong, 2024). Addressing the supply of learning resources, as well as improving teacher efficacy through continuous training, will ensure the sustained success of combined Science classrooms in Malaysia's vernacular schools (Isa, 2021; Chen et al., 2023).

To conclude, there are many opportunities to maximize the effectiveness of combined Science classes not only in Tamil Vernacular Schools but in general. This can be achieved by means of adopting collaborative pedagogical approaches, professional teacher support, and by using contextually relevant resources in a framework of constant investments and professional growth. Addressing ongoing resource gaps and expanding research on innovative technologies and family involvement is essential to ensuring equitable and high-quality Science education for all students in Malaysia's vernacular schools (Ong & Manikam, 2014; Muthiah & Suppiah, 2024).

This is a significant addition to scientific literature by offering comprehensive analysis of the effectiveness of combined science classes in Malaysian Tamil vernacular schools. The specified context is essential, but it is not represented in educational research well, and in the context of science education, in particular. This is the case with Tamil vernacular schools, which serve mostly the Tamil minority in Malaysia and which should obtain specific academic interest. The research identifies the innovative pedagogical practices deployed in these schools and the difficulties that are involved by looking at the integration of sciences subjects in these schools.

This paper theoretically penetrates the debate on the topic of inclusive and equitable education inclusive science, which is becoming a prominent focus in education reform worldwide. The review highlights the use of combined science classes by highlighting the way the teaching model supports differentiated learning and therefore, students with different academic abilities can access the curriculum at their different levels. Under those circumstances such practices that combine teaching methods arise as the most important strategy in this kind of environment where educators in diverse subjects within the field offer a coordinated way of teaching science. Such a partnership not only helps in making the learning experience more interesting but also educates the opportunity to use diverse teaching methods and teaching resources that can support the needs of the students with disabilities.

Moreover, an important point that is addressed in this review is curriculum integration. The curriculum can be conveyed by combining the different science subjects in a single class and changed into a more practical format that relates theory to the real world events to provide students with learning experience that relates theory to practice. This mix practice could help in the development of deeper insights and critical thinking by the students and this is crucial towards their general academic achievement. Another issue discussed in the review is the role of combined science classes in Tamil vernacular schools in overcoming the disconnection between various sciences, resulting in learning that is more holistic and involving to students.

Contextually the review illuminates on the difficulties that Tamil vernacular schools face in Malaysia. Although they play a vital role in maintaining a Tamil language and culture,

these schools are most of the time strained in terms of resources, both material and human. The paper shows how these schools overcome these shortcomings and yet endeavor to deliver good science education. The review gives an idea of the way that the teachers in the Tamil, vernacular schools manage to survive with the limited access to the teaching resources like laboratory equipment and textbooks and, nonetheless, provide an atmosphere that fosters the scientific investigation and study. It is also a part of this discussion that validates the need of more specialized teacher training and professional development.

The review also reveals the prevalent pedagogical contents that have been effective in the process of implementing the combined science classes. These trends involve the active learning methodologies, the collaboration with other peers, and the application of technology to facilitate active learning. Nevertheless, other critical flaws in the existing performance of combined science classes in Tamil vernacular schools are also found in the review, continuing to apply innovative teaching strategies and mastering standard assessment practices. The gaps are an indication of what needs to be improved and AI values how to undertake future research and intervention.

In conclusion, this research is related to some significant conclusions that can be given to fillers, policymakers, and scholars who are interested in enhancing science education in the minority language schools. The review, by helping to close a significant localized research financial void in the educational field, offers a structure through which the complications associated with teaching science in diverse and multilingual settings may be explained. The results are also relevant to Tamil vernacular schools but also to any other multilingual and multicultural school experiences across the globe, with strategies likely to be customized to suit different environments that would foster inclusive and equitable learning.

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