



Development and Functional Testing of BETAPA ANTIK 2.0: An Android-Based Mobile Application for Community Dengue Surveillance and Reporting in North Sumatra, Indonesia

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<p>Track Record Article</p> <p>Revised: 03 June 2026 Accepted: 21 June 2026 Published: 24 June 2026</p> <p>How to cite : Tanjung, R., Nolia, H., Sinaga, J., Damanik, A. W., Syaputri, D., Manalu, S. M. H., & Tanjung, N. (2026). Development and Functional Testing of BETAPA ANTIK 2.0: An Android-Based Mobile Application for Community Dengue Surveillance and Reporting in North Sumatra, Indonesia. <i>Contagion: Scientific Periodical Journal of Public Health and Coastal Health</i>, 8(2), 349–360.</p>	<p style="text-align: center;">Abstract</p> <p><i>Dengue fever remains a major public health concern in Indonesia, particularly in tropical regions such as North Sumatra, where Deli Serdang Regency reports persistently high case numbers. Conventional larva surveillance and the 1 House 1 Larva-Monitor movement (GIRIJ) still rely on manual, paper-based reporting that is slow, poorly documented, and difficult to coordinate in real time. The initial BETAPA ANTIK 1.0 application supported larva-survey reporting but lacked educational video content and adult mosquito identification tools, limiting its utility for community education and vector surveillance. This study aims to develop and functionally test BETAPA ANTIK 2.0 (Based on Larvae Surveillance and Analysis Technology), an Android-based mobile application, incorporating GPS-based location tracking, digital case reporting, multimedia public education, and an adult-mosquito identification camera. A design-and-development (Research and Development) approach was employed, following the Waterfall software-development life cycle: requirements analysis, system design, implementation, testing, and maintenance. The application was built on the Android platform using Kotlin/Java, and functional verification was conducted through black-box testing of each feature. BETAPA ANTIK 2.0 provides five core modules: GPS enabled geotagging, a digital reporting workflow integrated with WhatsApp and Gmail, video and poster-based educational media, and an adult-mosquito identification camera covering 23 species. All functional (black-box) test cases performed according to specifications, with the only limitation being dependence on a stable internet connection. Usability, user acceptance, and the accuracy of mosquito-identification were not formally evaluated and are identified as priorities for future studies. BETAPA ANTIK 2.0 was successfully developed and passed functional (black-box) testing, representing a promising digital tool to support participatory dengue surveillance and reporting. However, its effectiveness in dengue control requires further field implementation and usability evaluation. Recommended next steps include developing an offline mode, risk-zone notifications, and integration with existing health information systems.</i></p> <p>Keywords: <i>Dengue Prevention and control, Mosquito Vectors, Mobile Applications, Epidemiological Surveillance, Community Participation, Indonesia</i></p>
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INTRODUCTION

Dengue hemorrhagic fever (DHF) is a tropical disease that poses a global health challenge and remains endemic in many countries, including Indonesia. It is caused by the dengue virus, transmitted through the bites of *Aedes aegypti* and *Aedes albopictus* mosquitoes (World Health Organization, 2025). According to the WHO, dengue incidence continues to rise across tropical regions, with Southeast Asia bearing a particularly heavy disease burden (EClinicalMedicine, 2024; Lancet, 2024; World Health Organization, 2025). In Indonesia, DHF remains one of the leading causes of morbidity and mortality from infectious diseases,

with incidence rates increasing annually, and the cases now reported in all provinces (Dinas Kesehatan Provinsi Sumatera Utara, 2024; Mamenun et al., 2024).

The rise in dengue fever cases is driven by several factors, including climate change, which affects vector behavior and geographic distribution, rapid urbanization, and inadequate environmental sanitation (Lancet, 2024; Mamenun et al., 2024; Salim et al., 2024). In North Sumatra, particularly Deli Serdang Regency, dengue fever poses a significant burden due to high humidity and population density, which facilitate mosquito breeding and the formation of case clusters (Dinas Kesehatan Provinsi Sumatera Utara, 2024; Faridah et al., 2021; Sinaga et al., 2023).

According to the North Sumatra Provincial Health Office, the province recorded 4,452 dengue fever cases in 2023, corresponding to an incidence rate (IR) of 29.5 per 100,000 population and a case fatality rate (CFR) of 0.47% (21 deaths). This represented a decline from 8,541 cases (IR 56.5 per 100,000; CFR 0.7%) in 2022. Within the province, Deli Serdang Regency reported 665 cases in 2023—the second-highest number after Medan City. The case burden in Deli Serdang has remained high for several years, rising from 997 cases (incidence rate of 46.3 per 100,000) in 2019 to 1,326 cases in 2020. This persistently high burden, combined with humid conditions and densely populated settlements, was the basis for selecting Deli Serdang as the focus of this study (Dinas Kesehatan Provinsi Sumatera Utara, 2024)

Mosquito breeding site elimination (PSN) and the “1 House, 1 Larva Monitor” (G1R1J) campaign are national dengue control strategies that rely heavily on active community participation, as well as the knowledge, attitudes, and practices of households and volunteers (Gregorio et al., 2024; Nanda et al., 2023). However, traditional paper-based approaches to larval monitoring and case reporting often face challenges such as incomplete documentation and delayed responses due to their manual nature. Information technology innovations, particularly mobile applications, therefore represent a promising approach improving the effectiveness and efficiency of vector surveillance and early case reporting.

Smartphone applications that integrate location services and multimedia can facilitate real-time reporting, provide public education, and support interactive identification of adult mosquito species (Dane et al., 2021; Melo et al., 2024). As a rapidly evolving open platform, Android offers significant opportunities to develop health apps that are easily accessible to both field workers and the general public (Moungui et al., 2024). By combining GPS, cameras, and messaging services, mobile apps can enhance community participation while accelerating health workers' response efforts (Perdani et al., 2021).

Although mobile tools are available, dengue fever monitoring in Indonesia still relies heavily on manual reporting. Existing digital tools are primarily district-level Geographic Information System (GIS) dashboards and larval density reporting systems operated by health departments, for example, integrated environmental monitoring apps for the continuous reporting of case and larval data (Salim et al., 2024). Tools designed for residents that sustain community participation and link reports directly to health center remain scarce. Internationally, integrated apps such as Mozzify in the Philippines combine real-time case reporting and mapping with in-app educational videos and symptom checkers (Dane et al., 2021), while deep-learning-based image classification has been used to identify *Aedes* species from photos to support community-based vector control (Nolte et al., 2024). However, few tools combine geotagged citizen reporting, multimedia education, and adult mosquito identification within a single, locally adapted interface.

Version 1.0 of BETAPA ANTIK supported larval survey reporting but has two major limitations: it lacked educational video content and did not include a feature for identifying adult mosquitoes (Damanik et al., 2025). These shortcomings reduced its value as a tool for public education and vector identification. To address these gaps, version 2.0 was developed with additional features, including GPS-based geotagging, a structured digital reporting workflow, educational videos and posters, and a camera for adult mosquito identification. The development and implementation plan for this app was guided by the Technology Acceptance Model (TAM), which posits usefulness and perceived ease of use predict user acceptance (Mahotra et al., 2024), as well as the World Health Organization's (WHO) Global Digital Health Strategy 2020–2025, which emphasizes participatory mobile tools to strengthen surveillance and community engagement (World Health Organization, 2021)

The objective of this study was to develop BETAPA ANTIK version 2.0 and to verify, through functional testing, that its new features operate as designed, thereby enabling subsequent evaluation of its usability and effectiveness in supporting community-based dengue surveillance and reporting.

METHODS

Study design

This study was a design-and-development project, also referred to as Research and Development (R&D), aimed at producing and functionally testing a software product. The development process followed the Waterfall software-development life cycle, comprising five sequential stages: requirements analysis, system design, implementation (coding), testing, and

maintenance. Within the design stage, iterative refinement of the user interface was conducted with prospective users; this refinement was considered part of the Waterfall design stage and was not presented as a separate overall methodology.

Development environment

The application was developed for the Android platform using the Kotlin/Java programming languages, with a client–server architecture and a database to store user profiles, reports (questionnaires), and location data.

Participants and needs assessment

During the requirements-analysis stage, user needs were identified through interviews with prospective users, community members, Jumantik/G1R1J coordinators, and health-center staff, alongside a literature review, in order to define the expected application features. An early prototype was then presented to prospective users for evaluation, and their feedback was used to refine the user interface during the design stage. Because the present work was a development-and-functional-testing study, no formal participant sampling for a usability trial was undertaken at this stage. A structured usability and acceptance evaluation with a defined participant sample is planned as a separate follow-up study (see *Usability and acceptance evaluation, and Limitations*).

Functional testing

Each implemented feature was verified using black-box testing, which evaluates whether a function produces the expected output for a given input without examining the internal code. Test cases included the reporting workflow, GPS/location capture, photo upload, educational-content playback, the mosquito-identification camera, and the login system distinguishing admin and public access. A feature was recorded as “pass” when it performed according to its functional specification and “fail” when it did not, in which case the defect was logged and corrected. Results are presented in Table 1, together with the outcomes for each core module and any limitations observed.

Usability and acceptance evaluation

Usability, user acceptance, and real-world effectiveness were beyond the scope of this development-and-functional-testing study; these aspects are identified as priorities for a dedicated follow-up evaluation using validated instruments such as the System Usability Scale (SUS) or a TAM-based questionnaire (see *Limitations and Conclusion*).

Data analysis

Functional test outcomes were summarized descriptively as pass/fail per module and tabulated using Microsoft Excel. No inferential statistical analysis was required for this

development-and-functional-testing study. In future work, where usability data are collected SUS scores will be summarized using descriptive statistics and interpreted against established SUS benchmarks, while any qualitative interview data will be analyzed thematically.

Ethical considerations

Ethical approval for this study was granted by the Health Research Ethics Committee (*Komisi Etik Penelitian Kesehatan*) of the Health Polytechnic, Ministry of Health, Medan (Poltekkes Kemenkes Medan), under approval number 01.1737/KEPK/POLTEKKES KEMENKES MEDAN/2023, dated 28 April 2023. Informed consent was obtained from all participants — represented by household members/respondents — prior data collection. Because the application captures GPS coordinates and household addresses and routes reports through WhatsApp and Gmail, personal and location data were managed to ensure that reports were directed only to the authorized G1R1J coordinator at each health office.

RESULT

This section presents the features introduced in BETAPA ANTIK version 2.0 and the results of functional testing. Interpretation and comparison with other systems are provided separately in the Discussion.

Location tracking (GPS camera)

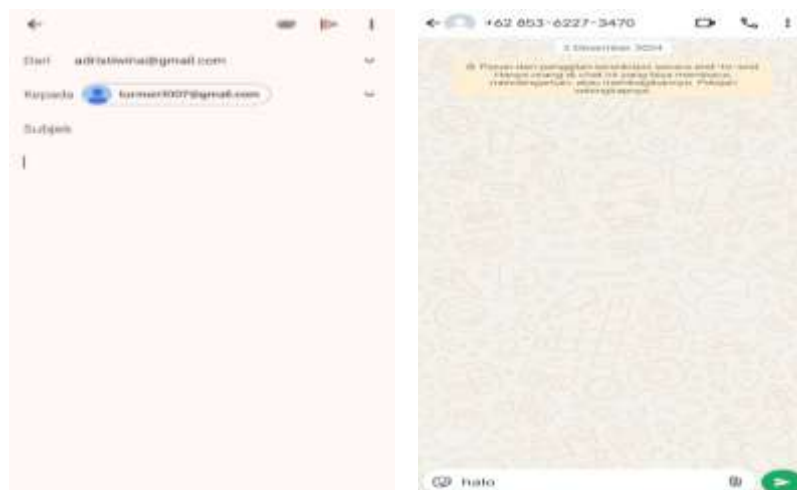
The location module collects and records the sites of reported dengue cases and potential breeding grounds. It is accessed through the health-center page, which lists 26 health-center locations, each linked to a questionnaire equipped with a GPS-enabled camera. For each entry, the application records the marked address, GPS coordinates (latitude and longitude), and the date and time of collection, thereby providing geotagged, time-stamped data.

Figures 1. Location Tracking

Digital reporting

The reporting module enables community members and health workers to report dengue symptoms or confirmed cases in their surroundings. Reports are transmitted via WhatsApp and

Gmail to the designated G1R1J coordinator at each health office and may include uploaded photographic evidence of environmental conditions (e.g. standing water, water reservoirs, and waste sites) along with the time symptoms first appeared. This process creates a rapid, digitally documented reporting trail.



Figures 2. Digital Reporting

Education: posters and video

The education module enhances public knowledge and engagement in dengue prevention. Posters provide easily readable information on the mosquito life cycle and mosquito-breeding site eradication (PSN), featuring an updated, more attractive design and an interactive “story circle” layout that describes mosquito types and characteristics. Unlike version 1.0, version 2.0 includes an educational video feature (Tanjung et al., 2025) designed to deliver prevention messages through memorable visuals and to motivate community participation in PSN.

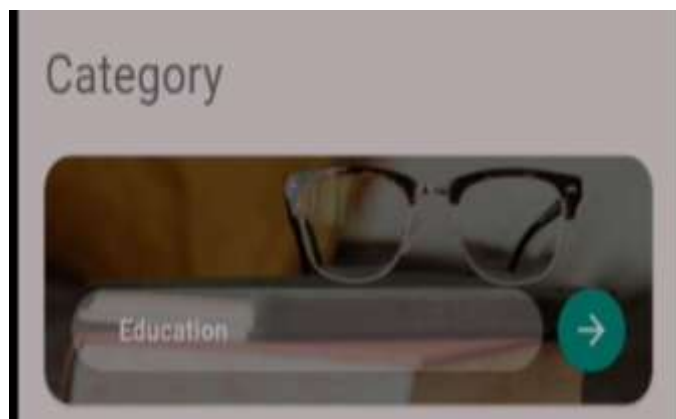
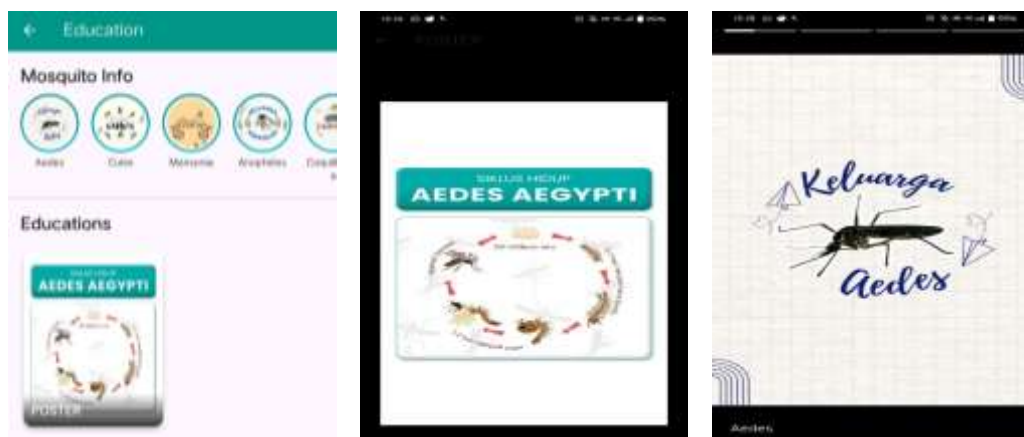
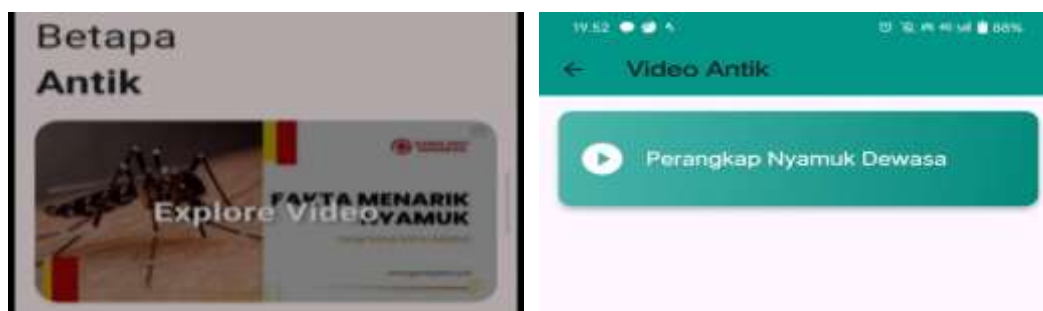


Figure 3. Education



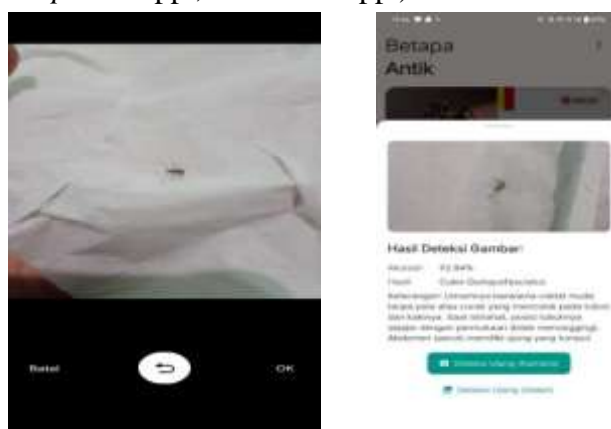
Figures 4. Poster



Figures 5. Video

Adult-mosquito identification camera

Absent in version 1.0, the identification camera is a key new feature in version 2.0. Users point the device camera at a mosquito to capture an image; after which the application identifies the mosquito species. This feature is designed to distinguish dengue vectors from non-vectors and references a database of 23 mosquito species (e.g. *Aedes aegypti*, *Aedes albopictus*, *Culex quinquefasciatus*, *Anopheles* spp., *Mansonia* spp.).



Figures 6. Identification Camera

The feature operates by capturing an image of a mosquito with the device camera and generating a candidate identification by referencing a curated library of 23 species compiled from the national mosquito and larva identification handbook (Kementerian Kesehatan

Republik Indonesia, 2019). Its accuracy against identifications made by a qualified entomologist has not yet been evaluated; therefore, the feature is described as *designed to identify* mosquito species rather than as a validated classifier, with formal validation identified as future work. For context, smartphone-based deep-learning classifiers of mosquitoes from body images have reported accuracies of approximately 79–93% (Nolte et al., 2024), providing a realistic benchmark for the planned validation.

Functional (black-box) testing results

Table 1 summarizes the functional testing of each core module.

Table 1. Results of black-box functional testing of the core modules.

Module / Test case	Expected result	Actual result	Pass / Fail
GPS camera captures coordinates + time	Address, lat/long, date/time saved	Address, coordinates, and timestamp recorded as expected	Pass
Report sent via WhatsApp/Gmail	Report delivered to G1R1J coordinator	Report delivered; coordinator notified without error	Pass
Photo upload with report	Image attached and stored	Image attached and stored with the report	Pass
Educational video playback	Video plays without error	Video and poster content played/displayed correctly	Pass
Mosquito identification camera	Returns mosquito type	Captured image and returned a mosquito-type result	Pass
Login (admin vs public)	Correct access level granted	Correct access level granted for admin and guest	Pass

All six core functional test cases behaved according to their specifications during testing, and no functional defect was left unresolved. The only limitation noted during testing was the application's dependence on a stable internet connection, because photo upload, survey-data capture, and educational-content access all require connectivity; this limitation is discussed below.

DISCUSSION

BETAPA ANTIK version 2.0 was developed to address specific gaps in version 1.0 by incorporating geotagged reporting, multimedia education, and an adult-mosquito identification camera. Functional testing confirmed that these features operate as intended. The following discussion interprets these results in the context of public health practice and existing tools.

Several mobile tools have been proposed for community-based vector surveillance, and BETAPA ANTIK 2.0 can be compared with them feature by feature. *Mozzify*, an integrated mHealth app from the Philippines, offers real-time case reporting and mapping alongside in-

app educational videos and an interactive symptom checker, but it does not provide adult-mosquito identification (Dane et al., 2021). The *NepaDengue* application improved dengue awareness and reported high acceptability using the Technology Acceptance Model, yet it emphasizes education and behaviour change rather than geotagged reporting or vector identification (Mahotra et al., 2024). Conversely, deep-learning image classifiers can identify *Aedes* species from photographs to support community vector control, but they lack case-reporting and education workflows (Akib et al., 2024; Nolte et al., 2024; Ong et al., 2021; Pise & Patil, 2023; Sauer et al., 2024). More broadly, geographic information systems, machine learning, and mobile applications are the digital tools most frequently deployed for dengue and arbovirus surveillance, and they are increasingly integrated within single programs (Faridah et al., 2021; Francisco et al., 2024; Leung et al., 2023; Mamenun et al., 2024; Melo et al., 2024; Salim et al., 2024; Sebastianelli et al., 2024). Within this landscape, BETAPA ANTIK 2.0 combines geotagged reporting, public education, and mosquito identification in a single, locally tailored interface, potentially lowering barriers to sustained community participation.

If adopted, real-time geotagged reporting could enable health-center staff to locate clusters and prioritize interventions more rapidly than paper-based G1R1J reporting. Multimedia education could support knowledge acquisition and behaviour change in the community (Gregorio et al., 2024); while an identification camera covering 23 species could, in principle, shift surveillance from a single-disease (dengue) focus toward integrated vector management, since species such as *Culex*, *Anopheles*, and *Mansonia* transmit other diseases (e.g. filariasis, malaria). These implications are stated conditionally because effectiveness has not yet been measured.

With further development, BETAPA ANTIK could be integrated with existing systems such as the Community Health Centre Information System (SIMPUS), the District Health Office dengue surveillance system, and endemic-zone dashboards. Such integration could reduce manual administrative burdens, accelerate response times, and improve the accuracy of epidemiological data, while also informing fogging-focus decisions, field-visit scheduling, and evaluation of the G1R1J movement. This integration is proposed as future work and has not yet been implemented.

This study has several limitations. First, evaluation was restricted to functional (black-box) testing; usability, user acceptance, and real-world effectiveness for dengue control were not assessed. Second, the application depends on a stable internet connection: core functions such as photo upload, survey data capture, and access to educational-content all require connectivity, which may exclude users in low-connectivity rural areas and contribute to under-

reporting in vulnerable communities. Third, the accuracy of the mosquito-identification camera has not yet been validated against expert entomologist identification. Fourth, field validation and integration with official surveillance systems remain outstanding. Additional potential limitations include reporting bias and unequal smartphone access.

CONCLUSION

This study successfully developed BETAPA ANTIK version 2.0 using the Waterfall software-development life cycle and verified, through black-box testing, that its core features; GPS-based location tracking, digital reporting via WhatsApp and Gmail, video and poster education, an adult-mosquito identification camera, and a login system separating admin and public access; operate as designed. The application represents a promising digital tool for participatory dengue surveillance and reporting and a clear advance over version 1.0.

However, this study demonstrates successful development and functional testing rather than proven effectiveness. The application's usability, user acceptance, and impact on dengue surveillance and control have not yet been evaluated and should be the focus of a dedicated field-implementation study. Future development should include an offline mode (e.g., local database syncing or progressive-web-app caching), risk-zone notifications, validation of the identification camera against expert entomologists, and integration with official systems such as SIMPUS. These efforts must be supported by a clear plan for data ownership, maintenance, and security to ensure a smooth transition from a university prototype to a Ministry of Health digital asset.

REFERENCES

- Akib, A., Karim, J., Mahmud, M. Z., & Id, R. K. (2024). Advanced vision transformers and open-set learning for robust mosquito classification : A novel approach to entomological studies. *PLOS Computational Biology*, *13*, 1–24. <https://doi.org/10.1371/journal.pcbi.1012654>
- Damanik, A. W., Sinaga, J., Nolia, H., & Tanjung, R. (2025). Aplikasi Survey Jentik BETAPAANTI K Dalam Mendukung Pengendalian Demam Berdarah Dengua Dengan Berbasis Teknologi Informasi. *Mitra Rafflesia*, *17*(1). <https://www.jurnal.stikesbhaktihusada.ac.id/index.php/mr/article/view/492>
- Dane, V. R., Herbuela, M., Karita, T., Carvajal, T. M., Tsai, H., Michael, J., Lorena, O., Regalado, R. A., & Dirilo, G. (2021). Early Detection of Dengue Fever Outbreaks Using a Surveillance App (Mozzify): Cross-sectional Mixed Methods Usability Study Corresponding Author : Related Article : *JMIR PUBLIC HEALTH AND SURVEILLANCE*, *7*(3), 1–16. <https://doi.org/10.2196/19034>
- Dinas Kesehatan Provinsi Sumatera Utara. (2024). *Profil Kesehatan Provinsi Sumatera Utara Tahun 2024*. dinkes.sumutprov.go.id
- EClinicalMedicine. (2024). Dengue as a growing global health concern. In *eClinicalMedicine* (Vol. 77). The Author(s). <https://doi.org/https://doi.org/10.1016/j.eclinm.2024.102975>

- Faridah, L., Mindra, I. G. N., Putra, R. E., Fauziah, N., & Agustian, D. (2021). Spatial and temporal analysis of hospitalized dengue patients in Bandung : demographics and risk. *Tropical Medicine and Health*, 49, 44. <https://doi.org/https://doi.org/10.1186/s41182-021-00329-9>
- Francisco, M. E., Carvajal, T. M., & Id, K. W. (2024). Hybrid Machine Learning Approach to Zero-Inflated Data Improves Accuracy of Dengue Prediction. *PLoS Negl Trop Dis*, 18(10), 1–22. <https://doi.org/10.1371/journal.pntd.0012599>
- Gregorio, E. R., Takeuchi, R., Hernandez, P. M. R., & Medina, J. R. (2024). Knowledge , attitudes , and practices related to dengue among public school teachers in a Central Luzon Province in the Philippines : an analytic cross - sectional study. *Tropical Medicine and Health*, 52, 25. <https://doi.org/10.1186/s41182-024-00591-7>
- Lancet, T. (2024). Dengue: the threat to health now and in the future. In *The Lancet* (Vol. 404, Issue 10450). Elsevier Ltd. [https://doi.org/10.1016/S0140-6736\(24\)01542-3](https://doi.org/10.1016/S0140-6736(24)01542-3)
- Leung, X. Y., Islam, R. M., Adhami, M., Ilic, D., Mcdonald, L., Palawaththa, S., Diug, B., Munshi, S. U., & Id, N. K. (2023). A systematic review of dengue outbreak prediction models : Current scenario and future directions. *PLoS Negl Trop Dis*, 17(3), 1–21. <https://doi.org/10.1371/journal.pntd.0010631>
- Mahotra, A., Pokhrel, Y., Thapa, T. R., Arguni, E., & Andono, R. A. (2024). Feasibility of NepaDengue mobile application for dengue prevention and control : user and stakeholder perspectives in Nepal. *BMJ Public Health*, 2(e000599), 1–14. <https://doi.org/10.1136/bmjph-2023-000599>
- Mamenun, Koesmaryono, Y., Sopaheluwakan, A., Hidayati, R., & Dasanto, B. D. (2024). Spatiotemporal Characterization of Dengue Incidence and Its. *Insects*, 15(5), 1–15. <https://doi.org/https://doi.org/10.3390/insects15050366>
- Melo, C. L., Mageste, L. R., Guaraldo, L., & Paula, D. P. (2024). Use of Digital Tools in Arbovirus Surveillance : Scoping Review Corresponding Author : *Journal of Medical Internet Research*, 26(e5747), 1–14. <https://doi.org/10.2196/57476>
- Moungui, H. C., Nana-djeunga, H. C., Anyiang, C. F., Cano, M., Antonio, J., Postigo, R., Carrion, C., & Moungui, H. C. (2024). Dissemination Strategies for mHealth Apps : Systematic Review Corresponding Author : *JMIR MHEALTH AND UHEALTH*, 12(e50293), 1–20. <https://doi.org/10.2196/50293>
- Nanda, M., Saragih, P. A., Nasution, D. H., Daulay, A., Sari, D. P., & Ridho, N. U. (2023). Analisis pengendalian faktor resiko dan vektor kejadian Demam Berdarah Dengue (DBD). *FLORONA : Jurnal Ilmiah Kesehatan*, 2(2), 111–116. <https://doi.org/10.55904/florona.v2i2.920>
- Nolte, K., Sauer, F. G., Baumbach, J., Kollmannsberger, P., & Lins, C. (2024). Robust mosquito species identification from diverse body and wing images using deep learning. *Parasites & Vectors*, 17(372), 1–8. <https://doi.org/10.1186/s13071-024-06459-3>
- Ong, S. Q., Ahmad, H., Nair, G., & Isawasan, P. (2021). Implementation of a deep learning model for automated classification of *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse) in real time. *Scientific Reports*, 11(9908), 1–12. <https://doi.org/10.1038/s41598-021-89365-3>
- Perdani, A. L., Komariah, R. N., & Srinatania, D. (2021). Penggunaan Aplikasi Mobile Technology untuk Deteksi Breeding Place Pencegahan Demam Dengue: Literature Review. *Risenologi*, 6(1a), 1–5. <https://doi.org/https://doi.org/10.47028/j.risenologi.2021.61a.207>
- Pise, R., & Patil, K. (2023). A Deep Transfer Learning Framework for the Multi-Class Classification of Vector Mosquito Species. *Journal of Ecological Engineering*, 24(9), 183–191. <https://doi.org/https://doi.org/10.12911/22998993/168501>
- Salim, M. F., Satoto, T. B. T., Danardono, & Danie, D. (2024). Digital Health Interventions in

- Dengue Surveillance to Detect and Predict Outbreak : A Scoping Review. *The Open Public Health Journal*, 17(e18749445283264), 1–15. <https://doi.org/10.2174/0118749445283264240116070726>
- Sauer, F. G., Werny, M., Nolte, K., Castro, C. V. De, Becker, N., Kiel, E., & Lühken, R. (2024). OPEN A convolutional neural network to identify mosquito species (Diptera : Culicidae) of the genus *Aedes* by wing images. *Scientific Reports*, 14(3094), 1–11. <https://doi.org/10.1038/s41598-024-53631-x>
- Sebastianelli, A., Spiller, D., Carmo, R., Wheeler, J., Nowakowski, A., Jacobson, L. V., Kim, D., Barlevi, H., El, Z., Cordero, R., González, F. J. C., Lowe, R., Ullo, S. L., & Schneider, R. (2024). A reproducible ensemble machine learning approach to forecast dengue outbreaks. *Scientific Reports*, 14(3807), 1–17. <https://doi.org/10.1038/s41598-024-52796-9>
- Sinaga, J., Tanjung, R., & Nolia, H. (2023). Environmental Analysis and Distribution Patterns of *Aedes Aegypti* Mosquito to Predict DHF Endemicity Area in Karo District. *Asian Journal of Engineering, Social and Health*, 2(10), 1102–1118. <https://doi.org/10.46799/ajesh.v2i10.143>
- World Health Organization. (2021). *Global strategy on digital health 2020-2025*. World Health Organization. <chrome-extension://efaidnbmninnibpcajpcgclclefindmkaj/https://iris.who.int/server/api/core/bitstreams/1f4d4a08-b20d-4c36-9148-a59429ac3477/content>
- World Health Organization. (2025). *Laboratory testing for dengue virus* (Issue April). <https://doi.org/https://doi.org/10.2471/B09394>