

SPATIALLY TARGETED DIARRHEA PREVENTION EDUCATION USING GEOGRAPHIC INFORMATION SYSTEMS: A COMMUNITY-BASED CASE FROM LOA JANAN, EAST KALIMANTAN

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Abstract

Diarrhoeal disease remains a preventable public health problem in which water, sanitation, hygiene (WASH), and health education are important intervention domains. However, community education is often delivered without explicitly linking prevention messages to the spatial distribution of local disease burden. This study evaluated the use of Geographic Information Systems (GIS) to visualize diarrhoea cases, identify an educational priority area, and deliver map-based prevention education in the working area of UPTD Puskesmas Loa Janan. A quantitative pre-experimental one-group pre-test and post-test design was complemented by descriptive qualitative feedback. Secondary diarrhoea case data from the health centre were aggregated by neighbourhood unit (RT) and mapped using QGIS 3.44.10. Thirty residents participated in an initial assessment of knowledge, attitudes, and preventive practices. Ten participants in the priority area completed the pre-test and post-test evaluation, and three participants were interviewed regarding map readability and colour classification. Descriptive statistics and the Wilcoxon signed-rank test were used to assess changes in knowledge. The health-centre records contained 411 diarrhoea cases during January–December 2025 and 109 cases during January–March 2026. The GIS map identified areas with higher case concentrations and was subsequently used as a visual risk-communication tool. All 10 evaluated participants had higher post-test scores than pre-test scores. The mean score increased from 49.00 to 78.00, while the median increased from 50.00 to 80.00. The Wilcoxon signed-rank test indicated a statistically significant difference between pre-test and post-test scores ($Z = -2.825$, $p = .005$). Participants were also able to interpret the map's four colour categories, although the activity did not use a standardized instrument to measure map literacy or behavioural change. GIS-based visualization can function not only as a surveillance and planning instrument but also as a locally contextualized medium for community health education. The approach links epidemiological information to places familiar to residents and can support targeted promotive and preventive action. Because the evaluation involved only 10 participants, lacked a comparison group, and measured knowledge immediately after education, the observed improvement should not be interpreted as evidence of a sustained or causal population-level effect.

Keywords: Geographic Information Systems, diarrhoea, health education, spatial mapping, risk communication, WASH, community health

Abstrak

Penyakit diare masih menjadi masalah kesehatan masyarakat yang dapat dicegah, dengan air, sanitasi, higiene (water, sanitation, and hygiene/WASH), dan pendidikan kesehatan sebagai domain intervensi yang penting. Namun, edukasi kepada masyarakat sering kali dilakukan tanpa

secara eksplisit menghubungkan pesan-pesan pencegahan dengan distribusi spasial beban penyakit di tingkat lokal. Penelitian ini mengevaluasi penggunaan Sistem Informasi Geografis (SIG) untuk memvisualisasikan kasus diare, mengidentifikasi wilayah prioritas edukasi, dan melaksanakan edukasi pencegahan berbasis peta di wilayah kerja UPTD Puskesmas Loa Janan. Penelitian menggunakan desain kuantitatif pre-experimental dengan rancangan one-group pre-test and post-test, yang dilengkapi dengan umpan balik kualitatif secara deskriptif. Data sekunder kasus diare dari pusat kesehatan masyarakat diagregasikan berdasarkan satuan wilayah Rukun Tetangga (RT) dan dipetakan menggunakan QGIS 3.44.10. Sebanyak 30 warga berpartisipasi dalam asesmen awal mengenai pengetahuan, sikap, dan praktik pencegahan. Sebanyak 10 peserta di wilayah prioritas mengikuti evaluasi pre-test dan post-test, sedangkan tiga peserta diwawancarai mengenai keterbacaan peta dan pemahaman terhadap klasifikasi warna. Statistik deskriptif dan uji Wilcoxon signed-rank digunakan untuk menganalisis perubahan pengetahuan. Data dari pusat kesehatan masyarakat menunjukkan terdapat 411 kasus diare selama Januari–Desember 2025 dan 109 kasus selama Januari–Maret 2026. Peta SIG berhasil mengidentifikasi wilayah dengan konsentrasi kasus yang lebih tinggi dan selanjutnya digunakan sebagai media komunikasi risiko secara visual. Seluruh 10 peserta yang dievaluasi memperoleh skor post-test yang lebih tinggi dibandingkan skor pre-test. Nilai rata-rata meningkat dari 49,00 menjadi 78,00, sedangkan nilai median meningkat dari 50,00 menjadi 80,00. Uji Wilcoxon signed-rank menunjukkan adanya perbedaan yang signifikan secara statistik antara skor pre-test dan post-test ($Z = -2,825$; $p = 0,005$). Peserta juga mampu memahami empat kategori warna pada peta, meskipun kegiatan ini belum menggunakan instrumen terstandar untuk mengukur literasi peta maupun perubahan perilaku. Visualisasi berbasis SIG tidak hanya dapat berfungsi sebagai instrumen surveilans dan perencanaan, tetapi juga sebagai media edukasi kesehatan masyarakat yang kontekstual dan berbasis kondisi lokal. Pendekatan ini menghubungkan informasi epidemiologis dengan lingkungan yang dikenal oleh masyarakat serta dapat mendukung tindakan promotif dan preventif yang lebih terarah. Namun, karena evaluasi hanya melibatkan 10 peserta, tidak menggunakan kelompok pembanding, dan mengukur pengetahuan segera setelah edukasi, peningkatan yang diamati tidak dapat diinterpretasikan sebagai bukti adanya perubahan yang berkelanjutan ataupun efek kausal pada tingkat populasi.

Kata kunci: Sistem Informasi Geografis, diare, pendidikan kesehatan, pemetaan spasial, komunikasi risiko, WASH, kesehatan masyarakat.

INTRODUCTION

Diarrhoeal disease remains a major public health concern because transmission is closely associated with contaminated water and food, inadequate sanitation, and insufficient hygiene practices. The World Health Organization identifies safe drinking-water, improved sanitation, handwashing with soap, food hygiene, and health education as important components of diarrhoea prevention (World Health Organization [WHO], 2024a, 2024b). Global monitoring likewise shows that substantial gaps remain in household access to safely managed water, sanitation, and hygiene services (WHO & UNICEF, 2023). Consequently, prevention requires not only biomedical or behavioural messages but also communication strategies that allow communities to recognize how health risks are distributed within their own environments.

Geographic Information Systems (GIS) provide a mechanism for converting tabular health records into spatially interpretable information. In public health, GIS has been used for disease surveillance, risk analysis, health-service planning, and community health profiling (McLafferty, 2003; Morris et al., 2003; Nykiforuk & Flaman, 2011; Rushton, 2003). Spatial visualization is particularly relevant to community interventions because it can identify areas that warrant greater attention and can help practitioners align limited educational resources with local patterns of disease burden. In Indonesia, previous studies have used GIS to map diarrhoea cases and related

environmental risk factors, including sanitation, water sources, drainage, population density, and access to health services (Fajriyah, 2023; Gea et al., 2023; Pertiwi & Widayani, 2019; Listyono et al., 2025; Widyastuti et al., 2025).

The communicative value of a map, however, depends on more than its technical accuracy. Maps are interpreted by non-specialist users whose health literacy, familiarity with symbols, and perceptions of risk may vary. Research on health-risk communication indicates that visual representations can improve understanding, but design choices such as colour, map type, simplicity, and contextual explanation influence how people perceive and interpret risk (Ancker et al., 2006; Few, 2006, 2012; Stieb et al., 2019; Fang et al., 2022; Tufte, 2001). Evidence on pictorial health communication similarly suggests that visual information can improve knowledge and recall, although effects vary across populations and interventions (Schubbe et al., 2020).

Health education is an established component of diarrhoea prevention. Evidence from systematic reviews indicates that handwashing promotion can reduce diarrhoeal disease risk (Bartram & Cairncross, 2010; Cairncross et al., 2010; Ejemot-Nwadiaro et al., 2021; Curtis et al., 2011), while broader WASH interventions are associated with reductions in diarrhoeal disease among children in low- and middle-income settings (Wolf et al., 2022). Recent evidence also suggests that community-based education, particularly when combined with audiovisual materials and behaviour-change communication, can improve preventive knowledge and hygiene-related behaviours, although intervention effects vary by context and study quality (Lima et al., 2026).

Despite this evidence, a practical gap remains between spatial surveillance and community education. Many mapping studies use GIS primarily to describe distributions or identify epidemiological risk factors, while health education studies often do not use local spatial information to select intervention targets. The present activity addresses this gap by integrating case mapping with targeted community education. Rather than treating the map solely as a technical product, the study uses it as a communication interface through which residents can connect epidemiological information with places they know.

Drawing on place-based epidemiological thinking, which treats health outcomes as shaped by spatial and social contexts (Krieger, 2003), the study therefore aimed to: (1) visualize the spatial distribution of diarrhoea cases in the working area of UPTD Puskesmas Loa Janan; (2) identify a priority area for community education based on case concentration; and (3) examine changes in participants' knowledge after map-based diarrhoea prevention education. The central contribution is a practice-oriented model in which GIS serves two sequential functions—targeting and communication—while acknowledging the methodological limits of a small, uncontrolled community evaluation.

METHOD

Study Design and Setting

The reporting of this nonrandomized intervention was informed by relevant guidance for transparent reporting of nonrandomized evaluations (Des Jarlais et al., 2004), although the activity was not a randomized trial. The activity used a quantitative pre-experimental one-group pre-test and post-test design, complemented by descriptive qualitative feedback on the usability of the visual medium. It was conducted on 22 May 2026 in the working area of UPTD Puskesmas Loa Janan, Kutai Kartanegara, East Kalimantan, with the community education session conducted in

RT 08, Desa Loa Janan Ulu. The health centre is located on Jalan Poros Samarinda–Balikpapan KM 04, Desa Loa Janan Ulu, Kecamatan Loa Janan. The study followed a pragmatic community-health orientation in which routinely available surveillance information was translated into an intervention-oriented visual product.

Data Sources and Participants

Two forms of data were used. Secondary data consisted of diarrhoea case records supplied by UPTD Puskesmas Loa Janan. The records contained 411 cases for January–December 2025 and 109 cases for January–March 2026. Primary data were collected through an initial questionnaire administered to 30 residents to assess baseline knowledge, attitudes, and preventive practices. From these 30 residents, 10 participants who attended the education session in the priority area and completed both measurements were included in the pre-test/post-test evaluation. Three participants were subsequently interviewed to obtain descriptive feedback on map readability, colour classification, and perceptions of local diarrhoea risk. Participation was conducted after permission had been obtained from the health centre and local community administrators. Participants received information about the activity, the knowledge evaluation, and documentation procedures and agreed to participate. Case data were aggregated at RT level; names, complete addresses, and individual coordinates were not displayed. Published documentation was presented with attention to participant privacy. These procedures were designed to reduce disclosure risks associated with mapping communicable-disease information.

Spatial Data Processing and Map Development

Case records and residential address information were first checked against the health-centre records and then aggregated by RT. The analysis was performed in QGIS version 3.44.10 (QGIS.org, 2025). Administrative boundaries were obtained from the health centre. Individual identifiers and exact residential points were excluded from the public-facing map. Case counts were classified into four operational categories: 0 cases, 1–4 cases, 5–8 cases, and more than 8 cases. The categories were determined from the observed range of RT-level case counts to facilitate interpretation rather than to represent standardized epidemiological thresholds. The resulting choropleth map used green for areas with no recorded cases, yellow for 1–4 cases, orange for 5–8 cases, and red for more than 8 cases. The map was then combined with supporting infographics and a flip-chart/lecture format during the education session. This design was informed by evidence that colour and map presentation can affect risk perception and comprehension (Fang et al., 2022), and by recommendations that risk maps should be designed around users' mental models, health literacy, and communication needs (Stieb et al., 2019).

Health Education and Outcome Measurement

Education addressed the definition of diarrhoea, causes and transmission, risk factors, WASH, handwashing with soap, and household prevention practices. The map was used at the beginning of the session to establish a locally recognizable risk context, after which prevention messages were discussed. The pre-test was administered before education and the post-test immediately after education. Knowledge scores were summarized using minimum, maximum, mean, median, and standard deviation. Normality was assessed using the Shapiro–Wilk test. Because the score distribution did not meet the normality assumption, the Wilcoxon signed-rank test was used with $\alpha = .05$. Interview responses were summarized descriptively to assess whether participants

understood the colour categories and how they perceived the map as a risk-communication medium.

Analytical and Interpretive Boundaries

The analysis distinguishes between three levels of evidence: (1) descriptive surveillance information from the health-centre records; (2) pre-test/post-test change among the 10 participants; and (3) qualitative feedback concerning map readability. No statistical association between WASH factors and diarrhoea cases was estimated, and no causal inference was made regarding the effect of education on disease incidence. The one-group design and immediate post-test also preclude conclusions about sustained behaviour change.

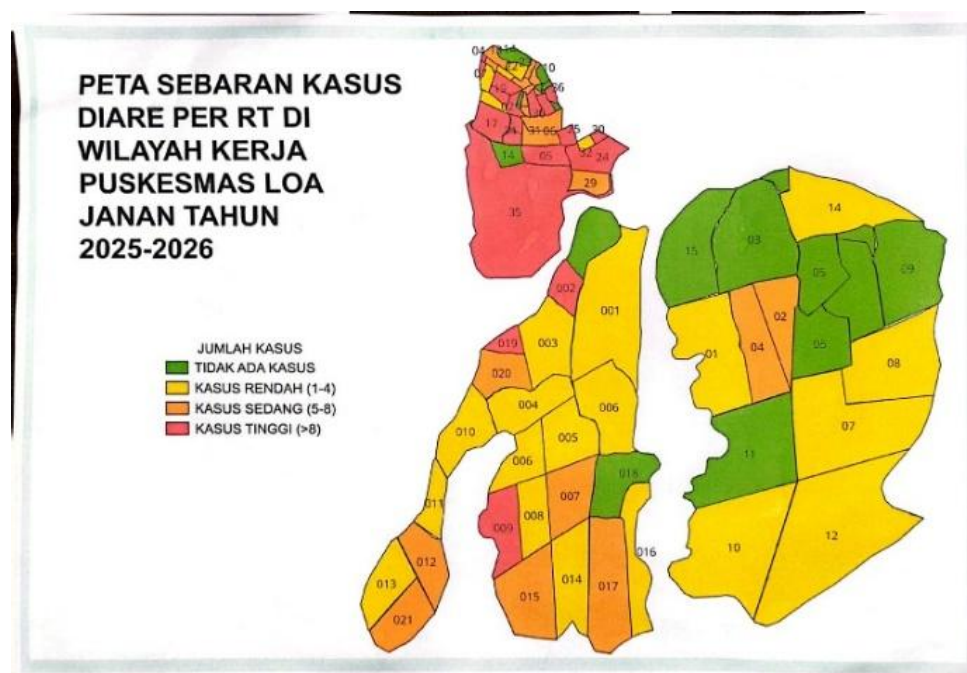
RESULTS AND DISCUSSION

Local Diarrhoea Burden and Spatial Targeting

The health-centre records contained 411 diarrhoea cases from January to December 2025, corresponding to an average of 34.3 cases per month. From January to March 2026, 109 cases were recorded, corresponding to an average of 36.3 cases per month. Because the two observation periods have different durations, these figures should not be interpreted as evidence of an annual increase. They nevertheless indicate a continuing local burden that justified prevention-oriented attention.

The GIS process transformed the tabular case records into an RT-level spatial distribution. The map made it possible to identify areas with greater concentrations of recorded cases and was used to select RT 08, Desa Loa Janan Ulu, as the location for the targeted education session. This use of GIS extends its conventional surveillance function by linking spatial information to immediate community intervention.

Figure 1. Spatial distribution of diarrhoea cases in the Puskesmas Loa Janan working area, January 2025–March 2026.



Baseline Assessment

The initial assessment of 30 residents indicated that most participants already had basic knowledge of diarrhoea prevention and generally positive attitudes toward clean and healthy living practices. However, preventive practices were not consistently implemented. Some residents reported that handwashing with soap was not habitual and that soap was not always available at handwashing facilities. These findings were used to emphasize practical household actions during the education session. The emphasis is consistent with evidence that hand hygiene and WASH are central components of diarrhoea prevention (Ejemot-Nwadiaro et al., 2021; WHO, 2024a).

Map-Based Risk Communication

During the education session, participants used the four colour categories to identify differences in RT-level case concentration. Green indicated no recorded cases, yellow indicated 1–4 cases, orange indicated 5–8 cases, and red indicated more than 8 cases. The three interview participants were able to explain the meaning of the colour categories. One participant living in a red-category area reported surprise after seeing the concentration of cases in the surrounding area. This response illustrates how spatial information can make an otherwise abstract epidemiological statistic more locally meaningful. The use of colour was not treated as a purely aesthetic decision. Evidence from map-based risk communication shows that colour schemes and map formats can affect visual cognition, comprehension, and risk perception (Fang et al., 2022). More broadly, reviews recommend designing health-risk maps with explicit attention to user characteristics, health literacy, risk perception, and the ethical implications of communicating localized risk (Stieb et al., 2019).

Changes in Knowledge

All 10 participants had higher post-test scores than pre-test scores. The pre-test scores ranged from 40 to 70, with a mean of 49.00, median of 50.00, and standard deviation of 9.944. Post-test scores ranged from 60 to 100, with a mean of 78.00, median of 80.00, and standard deviation of 13.166. The mean score therefore increased by 29 points descriptively.

Table 1. Descriptive statistics of participants' knowledge scores.

MEASURE	N	MINIMUM	MAXIMUM	MEAN	MEDIAN	SD
PRE-TEST	10	40	70	49.00	50.00	9.944
POST-TEST	10	60	100	78.00	80.00	13.166

Table 2. Wilcoxon signed-rank test of pre-test and post-test knowledge scores.

WILCOXON INDICATOR	VALUE	INTERPRETATION
POSITIVE RANKS	10	Post-test > pre-test
NEGATIVE RANKS	0	Post-test < pre-test
TIES	0	Post-test = pre-test

Z	-2.825	Wilcoxon signed-rank statistic
P (TWO-SIDED)	0.005	Statistically significant at $\alpha = .05$

The Wilcoxon signed-rank test produced 10 positive ranks, no negative ranks, and no ties ($Z = -2.825$, $p = .005$). The result indicates a difference between the pre-test and post-test scores within the evaluated participants. The finding is consistent with the broader evidence that health education can improve knowledge and preventive practices related to diarrhoeal disease, while the magnitude and durability of effects depend on intervention design and context (Ciptaningrum & Sudaryanto, 2024; Lima et al., 2026).

Figure 2. Community education using the spatial case-distribution map.



DISCUSSION

From Spatial Surveillance to Targeted Prevention

From a spatial epidemiology perspective, place-based patterns are useful for generating operational priorities, but they do not by themselves establish causal mechanisms (Krieger, 2003; Lawson, 2013; Morris et al., 2003). The main practical contribution of this activity is the integration of two functions that are frequently separated in community health work: spatial targeting and health education. GIS has long been recognized as a tool for surveillance, risk analysis, health-service planning, and community profiling (McLafferty, 2003; Morris et al., 2003; Nykiforuk & Flaman, 2011; Rushton, 2003; Lawson, 2013). In the present case, the map was not treated as the endpoint of analysis. Instead, the spatial distribution became a decision aid for selecting where education should be concentrated.

This distinction is important because a technically accurate map does not automatically produce a useful intervention. The public-health value of spatial information depends on whether decision-makers and community members can interpret the information and translate it into action. Stieb et al. (2019) emphasize the importance of understanding map users, risk perception, health literacy, and the purpose for which a map is developed. The Loa Janan activity operationalized

this principle by converting the map into a conversational educational medium rather than presenting it as a technical GIS product.

The approach also complements prior Indonesian studies that have primarily used GIS to describe diarrhoea distributions or environmental risk factors (Fajriyah, 2023; Gea et al., 2023; Pertiwi & Widayani, 2019; Listyono et al., 2025; Widyastuti et al., 2025). The novelty is therefore not the use of GIS itself, but its explicit integration with geographically targeted health education.

Spatial Visualization as Risk Communication

The participants' ability to interpret the four colour categories and the reported surprise among a participant living in a high-category area suggest that spatial visualization can make epidemiological information more concrete. This interpretation is supported by research showing that maps can function as health-risk communication tools when design is aligned with users' cognitive and health-literacy characteristics (Stieb et al., 2019). Studies of colour and map type similarly demonstrate that visual design can affect risk comprehension and perception (Fang et al., 2022).

The broader literature on visual health communication reaches a similar conclusion. Pictorial health information can improve knowledge and recall, particularly among audiences with lower health literacy, although substantial heterogeneity remains across interventions (Schubbe et al., 2020; Few, 2006, 2012; Tufte, 2001). Reviews of graphical risk communication also caution that visual simplicity and familiarity do not necessarily guarantee accurate interpretation; users may require explanation, and graphics can distort perceived risk when denominators or contextual information are absent (Ancker et al., 2006; Garcia-Retamero et al., 2012). Accordingly, the Loa Janan map was accompanied by direct facilitation rather than used as a stand-alone self-explanatory artifact.

Knowledge Improvement and the Role of WASH Education

The increase in knowledge scores after the education session is consistent with evidence that diarrhoea prevention education can improve knowledge and hygiene-related outcomes. Handwashing promotion has been shown to reduce diarrhoeal disease risk (Ejemot-Nwadiaro et al., 2021), while WASH interventions are associated with reduced diarrhoeal disease risk in low- and middle-income settings (Wolf et al., 2022). WHO guidance likewise identifies safe water, sanitation, handwashing with soap, food hygiene, and health education as core prevention measures (WHO, 2023, 2024a, 2024b). The present finding should nevertheless be interpreted as an immediate educational outcome rather than evidence of disease reduction. The participants were tested immediately after the session, and the design had neither a comparison group nor a follow-up assessment. A recent systematic review of controlled trials also highlights heterogeneity in educational interventions and follow-up periods, indicating that improvements in knowledge do not automatically establish sustained behavioural change or reductions in disease incidence (Lima et al., 2026).

Implications for Community Health Practice

The activity suggests a simple operational pathway for community health centres: routine case data → spatial aggregation → priority-area identification → map-based risk communication → immediate knowledge assessment → follow-up behavioural evaluation. Such a pathway can strengthen the connection between surveillance and health promotion without requiring

sophisticated analytical models. The approach is particularly suitable where health centres already maintain routine case records but need practical ways to translate those data into community-facing communication.

Three implementation principles emerge. Because hygiene behaviours are shaped by social, infrastructural, and environmental conditions rather than information alone (Dreibelbis et al., 2013; Sallis et al., 2008), maps should support—not replace—practical access to prevention resources. First, maps should use aggregation levels that protect confidentiality; the present activity used RT-level aggregation and did not display individual addresses or coordinates. Second, map categories should be accompanied by explicit legends and verbal explanation because visual elements are not interpreted uniformly. Third, educational evaluation should move beyond immediate knowledge to assess retention, self-reported practices, observed hygiene behaviour, and—where appropriate—subsequent disease indicators. These principles are consistent with broader evidence on actionable public-health visualization and risk communication (Ivanković et al., 2021; Narayan & Nayak, 2021; Schulze et al., 2023; Stieb et al., 2019).

Methodological Limitations

Several limitations constrain interpretation. First, only 10 participants were included in the pre-test/post-test evaluation, and they were selected from the residents attending education in the priority area; they do not represent the entire Puskesmas catchment population. Second, the one-group design cannot separate the effect of the education from testing effects, external information, or other contextual influences. Third, the post-test was administered immediately after education, so retention and behavioural change were not assessed. Fourth, the study did not statistically examine associations between WASH variables and diarrhoea cases. Fifth, the colour categories were operational categories based on the local case-count range, not standardized epidemiological risk thresholds. The small sample also limits precision and generalizability; p-values should not be interpreted as measures of effect magnitude (Greenland et al., 2016). Finally, the qualitative component used only three interviewees and a descriptive approach, so it should be understood as preliminary usability feedback rather than a formal qualitative evaluation.

CONCLUSION

The Loa Janan experience demonstrates that GIS-based visualization can serve a dual role in community diarrhoea prevention: it can identify priority areas from routine surveillance data and function as a contextualized medium for health-risk communication. The map enabled residents to connect case distribution with familiar neighbourhoods, while the accompanying education session was associated with higher immediate knowledge scores among the 10 evaluated participants ($Z = -2.825$, $p = .005$). The principal contribution is therefore the integration of spatial surveillance with targeted health education rather than GIS mapping alone. Nevertheless, the evidence is limited to a small, uncontrolled, immediate post-test evaluation. Future studies should involve larger samples, comparison groups, follow-up measurements, standardized instruments for map literacy and health behaviour, and integrated spatial analysis of WASH conditions and access to health services. Such designs would allow the potential of GIS-supported community education to be assessed more rigorously as a sustained public-health intervention.

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