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The Effectiveness of smart card education (early detection of preeclamsia risk) on the level of knowledge of pregnant women in Padangsidimpuan city Indonesia

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Abstract: Preeclampsia remains a leading cause of maternal mortality in Indonesia, particularly in regions with limited healthcare access such as Padangsidimpuan City. Low maternal knowledge regarding early detection significantly contributes to adverse outcomes. This qualitative study aimed to evaluate the effectiveness of a culturally adapted Smart Card–based education intervention on pregnant women's knowledge of preeclampsia risk factors, danger signs, and early detection behaviors in Padangsidimpuan City, Indonesia. A descriptive qualitative design with a phenomenological approach was employed. Data were collected through semi-structured in-depth interviews with 25 pregnant women and 8 midwives, and four focus group discussions (6-8 participants each) conducted between March and August 2025. The Smart Card intervention—a pocket-sized, laminated visual aid containing illustrated information on preeclampsia risk factors (history of hypertension, obesity, primigravida, maternal age), danger signs (severe headache, blurred vision, epigastric pain, edema), and action steps was introduced during antenatal care visits. Thematic analysis using the Framework Method was performed. Four major themes emerged: (1) substantial improvement in knowledge of preeclampsia risk factors and danger signs post-intervention; (2) the Smart Card's visual simplicity and portability facilitated active learning in the household context and enhanced spousal involvement; (3) empowerment in health-seeking behavior driven by increased risk awareness; and (4) barriers including low literacy and the need for facilitator guidance. The majority of participants demonstrated improved knowledge scores across all domains. The Smart Card education intervention is an effective, low-cost, and culturally appropriate tool for enhancing preeclampsia knowledge among pregnant women in resource-limited urban settings. Integration into standard antenatal care services is recommended.

Keywords: preeclampsia, early detection, smart card, health education, knowledge, pregnant women

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1. Introduction

Preeclampsia is a multisystem hypertensive disorder of pregnancy that typically manifests after 20 weeks of gestation and is characterized by new-onset hypertension (systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg) accompanied by proteinuria or evidence of maternal end-organ dysfunction. Globally, preeclampsia complicates approximately 2–8% of all pregnancies and accounts for an estimated 50,000 to 60,000 maternal deaths annually, with 99% of these fatalities occurring in low- and middle-income countries (LMICs). The condition is also responsible for significant perinatal morbidity, including intrauterine growth restriction, preterm birth, and stillbirth, making it one of the most pressing challenges in contemporary maternal-fetal medicine [1].

In Indonesia, the epidemiological burden of preeclampsia is particularly alarming. Data from the Indonesian Demographic and Health Survey indicated that hypertensive disorders of pregnancy, including preeclampsia, were the second most common cause of

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maternal death, accounting for 24–33.7% of all maternal mortality cases. The Indonesian Ministry of Health reported that maternal mortality ratio (MMR) remains at 305 per 100,000 live births, significantly higher than the Southeast Asian average and far from the Sustainable Development Goal (SDG) target of fewer than 70 per 100,000 live births by 2030. Preeclampsia's contribution to this persistent high MMR underscores the urgent need for effective preventive and early detection strategies [2].

The pathophysiology of preeclampsia is believed to originate from abnormal placentation in early pregnancy, with defective trophoblastic invasion of the spiral arteries leading to placental hypoperfusion, oxidative stress, and the release of antiangiogenic factors into the maternal circulation (soluble fms-like tyrosine kinase-1, soluble endoglin) that precipitate systemic endothelial dysfunction (Rana et al., 2019). Because the pathogenesis begins early long before clinical symptoms appear early identification of high-risk pregnancies during antenatal care (ANC) is paramount. The International Federation of Gynecology and Obstetrics (FIGO) recommends first-trimester screening using a combination of maternal risk factors, mean arterial pressure, uterine artery Doppler, and serum biomarkers. However, in many Indonesian healthcare settings, particularly at the primary care level (Puskesmas or community health centers), access to Doppler ultrasound, biochemical assays, and specialized training remains severely limited [3].

In such resource-constrained environments, maternal knowledge and awareness of preeclampsia risk factors and danger signs become a critical first line of defense. A substantial body of evidence indicates that insufficient knowledge regarding preeclampsia among pregnant women leads to delayed recognition of symptoms, late referral to higher-level care, and ultimately, preventable maternal and neonatal deaths. Studies conducted across various Indonesian regions have consistently reported low levels of preeclampsia knowledge. Research in Surabaya found that despite 56% of respondents having secondary education and 52% demonstrating good knowledge on a standardized questionnaire, significant disparities persisted along educational and parity lines, with lower knowledge levels associated with lower education attainment and nulliparity. Similarly, qualitative findings from Pandeglang Regency revealed that knowledge of early detection of preeclampsia remained low among pregnant women and their families, particularly in remote areas where healthcare access and health literacy were limited[4].

Padangsidimpuan City, located in North Sumatra Province with an estimated population of 225,000, typifies the challenges faced by mid-sized Indonesian cities in addressing maternal health. A previous study conducted at Padangsidimpuan Hospital in 2020 found that among 60 pregnant women, 12 (15.4%) were diagnosed with preeclampsia, and significant risk factors included a history of hypertension ($p=0.000$) and obesity ($p=0.001$). Despite the documented prevalence of these risk factors, the same study implied that many pregnant women remained unaware of their elevated risk status until clinical symptoms developed, underscoring the need for community-based educational interventions [5].

Health education has long been recognized as a cornerstone of primary prevention. However, conventional health education methods in Indonesian ANC settings—such as brief verbal counseling during consultation or distribution of generic leaflets—have shown limited effectiveness due to constraints in time, comprehensibility, and maternal engagement. A systematic review of educational interventions for hypertensive disorders of pregnancy found that while educational interventions consistently improve knowledge, their effectiveness depends heavily on the mode of delivery, with interactive and visually engaging materials outperforming passive dissemination methods. Interventions using booklets, pamphlets, videos, graphic cards, magnets, and PowerPoint presentations have all demonstrated positive outcomes, suggesting that multi-modal and patient-centered approaches are most effective [6].

The concept of the "Smart Card" (*Kartu Pintar*) as a health education medium has gained traction in Indonesian public health practice over recent years. Smart Cards are

typically credit-card-sized, laminated visual aids containing concise, illustrated information on specific health topics, designed for portability, durability, and ease of understanding. Research on Smart Cards for stunting prevention in Bengkulu City and Padang City demonstrated that Smart Card–based education significantly improved pregnant women's knowledge and attitudes toward stunting, with p-values <0.001 and large effect sizes. Similarly, the SEKAR card for anemia education in Samarinda improved knowledge and iron intake among pregnant women, and the "Mother's Smart Card" increased maternal vigilance in the management of pre-hospital childhood. These findings suggest that the Smart Card medium holds considerable potential for adaptation to other maternal health topics, including preeclampsia [7].

However, to date, no published study has examined the effectiveness of a Smart Card specifically designed for early detection of preeclampsia risk in the Indonesian context, and none has been conducted in Padangsidimpuan City. Furthermore, the majority of existing studies on Smart Card interventions and preeclampsia education have employed quantitative designs, which, while valuable for measuring effect sizes and statistical significance, are limited in their capacity to explore the nuanced experiences, perceptions, and contextual factors that shape how pregnant women receive, interpret, and act upon health information. Qualitative inquiry is essential for understanding the "how" and "why" behind observed outcomes, for identifying enabling factors and barriers to intervention implementation, and for capturing the subjective meanings that pregnant women attach to knowledge and behavior change [8].

A qualitative approach is particularly appropriate in the context of Padangsidimpuan, a city characterized by sociocultural diversity (predominantly Batak Angkola and Mandailing ethnic groups with strong kinship-based health decision-making patterns), varying levels of health literacy, and a health system that operates at the intersection of formal biomedical care and traditional practices. Understanding how pregnant women in this setting engage with a novel educational tool requires in-depth exploration of their lived experiences, the social dynamics of knowledge sharing within households, and the interactions between health providers and patients that either facilitate or impede learning. As noted by Siti Jumhati in her doctoral research at Universitas Indonesia, pregnant women's early detection behaviors for preeclampsia are most strongly influenced by the involvement of midwives and health cadres, healthcare provider attitudes, and support systems; these are inherently relational and context-dependent variables that demand qualitative investigation [9].

The present study was therefore designed to address three specific research questions: (1) How does a Smart Card education intervention affect pregnant women's knowledge of preeclampsia risk factors and danger signs in Padangsidimpuan City? (2) What are the subjective experiences and perceptions of pregnant women regarding the acceptability, usability, and relevance of the Smart Card medium? (3) What contextual factors (individual, interpersonal, and structural) facilitate or hinder the effectiveness of the Smart Card intervention in improving preeclampsia knowledge? By employing a qualitative research design with a phenomenological approach, this study aims to generate rich, contextualized evidence to guide the development of scalable and culturally sensitive educational interventions for maternal health in Indonesia and comparable settings.

The significance of this research extends beyond the local context of Padangsidimpuan. Indonesia's national health system, through the Jaminan Kesehatan Nasional (JKN) and the Maternal and Child Health (KIA) program, is actively seeking innovative, low-cost solutions to accelerate progress toward the SDG maternal mortality targets. If proven effective, the Smart Card model could be integrated into the existing "Buku KIA" (Maternal and Child Health Handbook) framework, distributed through Puskesmas and Posyandu networks, and adapted for various maternal health topics across the archipelago. This study thus contributes to the growing body of knowledge on implementation science in maternal health and provides a qualitative evidence base to inform policy and practice.

2. Method

This study employed a descriptive qualitative design with a phenomenological approach. The phenomenological approach was selected because the primary research objective was to understand and interpret the lived experiences of pregnant women as they engaged with the Smart Card educational intervention, focusing on their subjective perceptions, meaning-making processes, and behavioral responses. Phenomenology seeks to describe the essence of a phenomenon as experienced by individuals, making it well-suited for exploring how pregnant women perceive and utilize a health education tool within their specific sociocultural and healthcare contexts [10]. The descriptive dimension ensured that findings were grounded in rich, detailed narratives without imposing predetermined theoretical frameworks prematurely.

The study was conducted in Padangsidimpuan City, North Sumatra Province, Indonesia. With a population of approximately 225,000 inhabitants, Padangsidimpuan is the administrative and economic center of the region, characterized by a multi-ethnic composition predominantly comprising Batak Angkola and Mandailing communities. The city's healthcare infrastructure includes one public hospital (RSUD Kota Padangsidimpuan), several private maternity clinics, and eight Puskesmas (community health centers) that provide integrated antenatal care services. This study was conducted across four purposively selected Puskesmas: Puskesmas Padangmatinggi, Puskesmas Sadabuan, Puskesmas Batunadua, and Puskesmas Hutaimbaru. These sites were selected to represent the geographic, socioeconomic, and demographic diversity of the city, including urban core, peri-urban, and semi-rural catchment areas.

The local health system follows the national ANC guidelines, with pregnant women expected to attend at least six ANC visits during pregnancy (two in the first trimester, one in the second trimester, and three in the third trimester). The standard of care includes blood pressure measurement, weight monitoring, fundal height assessment, tetanus toxoid immunization, iron and folic acid supplementation, and basic health education. Preeclampsia-specific education is not a structured component of routine ANC and is typically limited to brief verbal warnings if hypertension is detected.

The Preeclampsia Risk Detection Smart Card was designed collaboratively by the research team in consultation with obstetricians, midwives, health promotion specialists, and local community health workers. The card measured 8.5 cm × 5.5 cm (standard credit-card size), was printed on durable laminated paper, and featured full-color illustrations on both sides. The front side contained: (a) the title "Kartu Pintar Deteksi Dini Risiko Preeklampsia" (Smart Card for Early Detection of Preeclampsia Risk) in large, bold Indonesian; (b) a pictorial list of six major preeclampsia risk factors, each accompanied by a simple icon: history of hypertension (red heart), obesity (scale), primigravida (number "1" with baby), maternal age <20 or >35 (calendar), family history (family tree), and multiple pregnancy (two babies); (c) a risk scoring grid where women could check which risk factors applied to them. The reverse side contained: (a) a list of five danger signs with attention-grabbing icons: severe headache (lightning bolt on head), blurred vision (clouded eye), epigastric pain (stomach with pain symbol), sudden edema/swelling (swollen hand), and reduced fetal movement (baby with exclamation mark); (b) an action flowchart indicating that if any danger sign was experienced, the woman should immediately visit the nearest health facility, accompanied by an illustration of a midwife; and (c) contact information for the local Puskesmas and emergency services. The language was kept simple (sixth-grade readability level) and supplemented with visual cues to accommodate varying literacy levels.

Participants were recruited using purposive sampling with maximum variation. The following inclusion criteria were applied for pregnant women: (1) age 18 years or older, (2) currently in the second or third trimester of pregnancy (gestational age $\geqslant$14 weeks), (3) registered for ANC at one of the four participating Puskesmas, (4) willing to participate in the full study protocol including the Smart Card intervention and at least one interview, and (5) able to communicate in Indonesian or Batak Angkola/Mandailing (with interpreter

assistance). The second and third trimester were chosen because these are the periods during which preeclampsia risk becomes clinically relevant and knowledge acquisition can translate into timely behavioral action.

A total of 25 pregnant women were enrolled for in-depth interviews (IDIs). Sampling continued until data saturation was achieved defined as the point at which no new themes or significant variations in experience emerged from three consecutive interviews. Maximum variation was sought across the following characteristics: age (<20, 20–35, >35 years), parity (nulliparous, 1–2 children, 3+ children), educational level (primary, secondary, tertiary), employment status, and known risk factors for preeclampsia (history of hypertension, obesity). Additionally, 8 midwives who provided ANC services at the participating Puskesmas were purposively selected for IDIs to obtain provider perspectives on intervention implementation and observed changes in patient knowledge.

Four focus group discussions (FGDs) were conducted with 6–8 pregnant women each (total FGD participants: 28, with some overlap with IDI participants), stratified by Puskesmas location. FGDs aimed to explore shared norms, collective experiences, and social discourse regarding the Smart Card, supplementing the individual narratives obtained through IDIs.

Data collection took place from March to August 2025. The study was implemented in three phases:

Phase 1 (Pre-Intervention): At the first ANC visit following enrollment, participants completed a brief demographic questionnaire and a baseline knowledge assessment (10-item questionnaire covering risk factors and danger signs) administered orally by a trained research assistant to avoid literacy bias. Following the assessment, a semi-structured in-depth interview (IDI 1) was conducted with 15 of the 25 IDI participants to explore baseline knowledge, health beliefs regarding pregnancy complications, sources of health information, and expectations regarding health education. Each interview lasted 45–60 minutes and was audio-recorded with participant consent.

Phase 2 (Intervention Delivery): Within one week of enrollment, eligible pregnant women received the Preeclampsia Risk Detection Smart Card during a dedicated 20-minute education session led by a trained research midwife at the Puskesmas. The session included: (a) distribution of the Smart Card; (b) a guided walk-through of both sides of the card, with the midwife explaining each risk factor and danger sign; (c) individualized risk assessment in which the midwife and participant jointly completed the risk scoring grid; (d) demonstration of how to use the card for self-monitoring; (e) encouragement to share the card with family members, particularly the husband; and (f) an opportunity for questions and clarification. Participants were asked to carry the card with them and to refer to it regularly.

Phase 3 (Post-Intervention): At 4–6 weeks after the intervention delivery (coinciding with a subsequent ANC visit), follow-up IDIs (IDI 2) were conducted with all 25 participants to explore their experiences using the Smart Card, changes in knowledge and awareness, sharing of information with family members, health-seeking behaviors, and perceptions of the card's utility and acceptability. Additional questions explored barriers and facilitators to using the card. The 10-item knowledge assessment was re-administered. For participants who participated in IDI 1, paired analysis of pre- and post-intervention narratives was conducted. FGDs were conducted after the completion of all IDI 2 interviews to triangulate findings and explore collective experiences.

All interviews and FGDs were conducted in a private room at the Puskesmas or, if preferred by the participant, at the participant's home, ensuring confidentiality. A female interviewer fluent in both Indonesian and Batak Angkola/Mandailing conducted all sessions. For participants who preferred the local language, a bilingual co-facilitator provided real-time interpretation during the interview, and audio recordings were later transcribed and translated. Field notes documented non-verbal cues, contextual observations, and interviewer reflections.

Data analysis employed the Framework Method, a systematic approach to thematic analysis particularly suited for applied qualitative research where research questions are specified in advance and multiple data sources are triangulated (Gale et al., 2013). The analysis proceeded through seven stages:

Transcription: All audio recordings were transcribed verbatim in the original language and then translated into Indonesian (if in Batak) and English for analysis. A bilingual research assistant verified translations for accuracy.

Familiarization: The research team (SN, RAP, DS) independently read through all transcripts and field notes to become immersed in the data and gain an overall sense of participants' experiences.

Coding: An initial coding framework was developed inductively from the first five transcripts through open coding. Codes were generated line-by-line using NVivo 14 software (QSR International, 2024). The research team met to discuss and harmonize codes, resolving discrepancies through consensus.

Developing a Working Analytical Framework: Codes were grouped into categories based on thematic similarity, resulting in an initial analytical framework. This framework was iteratively refined as new transcripts were coded.

Applying the Analytical Framework: The finalized framework was systematically applied to the entire dataset. Each transcript was coded by two independent researchers (SN and RAP) to enhance reliability, with inter-coder agreement of 87% (Cohen's kappa = 0.82 indicating excellent agreement).

Charting Data into the Framework Matrix: Summarized data were charted into a matrix in NVivo, with rows representing participants (cases) and columns representing themes and sub-themes. This matrix facilitated cross-case comparison, pattern identification, and examination of variation across participant characteristics.

Interpreting the Data: Themes were elaborated, connections between themes were explored, and findings were situated within the existing literature. Representative quotations were selected to illustrate key findings.

Trustworthiness was established following Lincoln and Guba's (1985) criteria. Credibility was ensured through prolonged engagement (three months of fieldwork), triangulation of data sources (IDIs, FGDs, midwife interviews, field notes), and member checking with five participants who reviewed and confirmed the accuracy of preliminary findings. Transferability was promoted through thick description of the research context, participant characteristics, and intervention details to allow readers to assess applicability to other settings. Dependability was addressed by maintaining a detailed audit trail of methodological decisions, coding processes, and analytical refinements. Confirmability was strengthened through reflexive journaling by the lead researcher throughout the data collection and analysis process, documenting personal biases, assumptions, and their potential influence on interpretation.

Ethical approval for this study was obtained from the Health Research Ethics Committee of Aufa Royhan University, Padangsidimpuan (Approval No. 045/KEPK-UNAR/III/2025). All participants provided written informed consent prior to enrollment. For participants with limited literacy, the consent form was read aloud, and verbal consent was witnessed and documented by an independent witness. Participants were informed of their right to withdraw at any time without consequence to their ANC services. Confidentiality was maintained by assigning unique identification codes to all participants and storing data in password-protected files accessible only to the research team. No financial incentives were provided; however, participants received a small token of appreciation (a baby care kit valued at approximately IDR 30,000, equivalent to USD 2). Participants identified as having high preeclampsia risk based on the Smart Card assessment were referred for further evaluation according to standard clinical protocols, independent of their study participation status

3. Result & Discussion

A total of 25 pregnant women participated in the in-depth interviews, with 28 additional women participating in four focus group discussions (some overlap between IDI and FGD participants, with 42 unique individuals overall). The mean age of IDI participants was 28.6 years (range 19–41 years). Table 1 presents the sociodemographic and obstetric characteristics of the 25 IDI participants.

Table 1. Sociodemographic and Obstetric Characteristics of In-Depth Interview Participants (n = 25)

Characteristic	Category	Frequency (n)	Percentage (%)
Age Group (years)	< 20	3	12.0
	20–35	17	68.0
	> 35	5	20.0
Parity	Nulliparous	8	32.0
	1–2 children	12	48.0
	≥3 children	5	20.0
Educational Level	Primary (≤SD)	5	20.0
	Secondary (SMP/SMA)	15	60.0
	Tertiary (D3/S1)	5	20.0
Employment Status	Housewife	17	68.0
	Employed (formal/informal)	8	32.0
Gestational Age at Enrollment	2nd trimester (14–27 wks)	11	44.0
	3rd trimester (≥28 wks)	14	56.0
Known Preeclampsia Risk Factors*	History of hypertension	5	20.0
	Obesity (BMI ≥ 30)	6	24.0
	Family history of preeclampsia	4	16.0
	Age risk (<20 or >35)	8	32.0
Number of ANC Visits Attended (current pregnancy)	2–3 visits	9	36.0
	4–5 visits	12	48.0

	≥6 visits	4	16.0
Primary Language	Indonesian	14	56.0
	Batak Angkola/Mandailing	11	44.0

The nutritional analysis confirmed that the vacuum-fried salacca chips retained a substantial proportion of the iron and vitamin C content of the fresh fruit. The results are presented in Table 2, which compares the nutritional profile of the salacca chips with fresh salak fruit and commonly consumed commercial children's snacks.

As shown in Table 1, the majority of participants were aged 20–35 years (68%), had 1–2 children (48%), had completed secondary education (60%), and were housewives (68%). Over half (56%) were in their third trimester at enrollment. Nearly one-third had age-related risk for preeclampsia (32%), and 24% were classified as obese. These characteristics reflect the typical profile of pregnant women attending ANC at Puskesmas in Padangsidimpuan and are consistent with previously reported data from the region.

The 8 midwives who participated in IDIs had a mean age of 34.2 years, an average of 9.6 years of clinical experience, and had all completed a Diploma III Midwifery (D3 Kebidanan) program.

While this study is primarily qualitative, knowledge scores from the 10-item questionnaire were compiled to provide contextual descriptive data. Table 2 presents the comparison of pre- and post-intervention knowledge scores.

Table 2. Comparison of Pre- and Post-Intervention Knowledge Scores (n = 25)

Knowledge Domain	**Pre-Intervention Mean Score ± SD (%)**	**Post-Intervention Mean Score ± SD (%)**	**Mean Change (%)**
Risk Factor Knowledge (5 items)	2.2 ± 1.3 (44.0%)	4.1 ± 0.8 (82.0%)	+38.0
Danger Sign Knowledge (5 items)	2.5 ± 1.4 (50.0%)	4.3 ± 0.7 (86.0%)	+36.0
Total Knowledge (10 items)	4.7 ± 2.1 (47.0%)	8.4 ± 1.2 (84.0%)	+37.0

The mean total knowledge score improved from 47% pre-intervention to 84% post-intervention, representing a mean improvement of 37 percentage points. All individual participants demonstrated improvement, though the magnitude of change varied. Participants with primary education had lower baseline scores (mean 2.8/10, 28%) compared to those with tertiary education (mean 6.4/10, 64%), but both groups showed substantial gains post-intervention (to 7.2/10 and 9.4/10, respectively). The descriptive knowledge score data are consistent with the qualitative findings on knowledge improvement reported below.

Analysis of the qualitative data yielded four overarching themes, each with multiple sub-themes, describing the effectiveness, acceptability, and contextual influences of the Smart Card education intervention on pregnant women's knowledge of preeclampsia.

Theme 1: Transformation of Knowledge From Vagueness to Clarity

The most pervasive finding across all participant narratives was the substantial improvement in knowledge regarding preeclampsia what it is, who is at risk, what signs to watch for, and what actions to take. Prior to the intervention, the majority of participants demonstrated fragmented, vague, and often inaccurate understanding of preeclampsia.

At baseline, many participants had never heard the term "preeklampsia," or if they had, they associated it vaguely with "high blood pressure during pregnancy" without understanding its specific implications. A 24-year-old nulliparous participant from Puskesmas Sadabuan (P05, IDI-1) stated:

"I've heard about high blood pressure in pregnancy, but honestly, I didn't know it was called preeclampsia. The midwife said my blood pressure was normal, so I thought I didn't need to worry about anything. I didn't know there were other signs to watch for besides blood pressure."

A 36-year-old multigravida (P12, IDI-1) who had a previous hypertensive pregnancy but had never received a formal diagnosis of preeclampsia recalled:

"In my last pregnancy, my feet got very swollen and I had a bad headache. My mother told me it was normal in late pregnancy. I didn't go to the midwife because I thought it was just part of being pregnant. Now I know that was dangerous."

For several participants, knowledge of risk factors was particularly limited. A 19-year-old primigravida (P18) stated:

"I thought only older women could get preeclampsia. I'm still young, so I felt safe. I didn't know that being young and in your first pregnancy is also a risk."

Following the Smart Card intervention, participants consistently described a transformed understanding characterized by specificity, confidence, and a sense of agency. A 29-year-old secundigravida from Puskesmas Batunadua (P08, IDI-2) expressed:

"Now I understand clearly what preeclampsia is. I know the risk factors—some of them apply to me, like my weight and because my mother had preeclampsia. I know exactly what symptoms to look for. If I get a headache that won't go away or if my vision becomes blurry, I know I must go to the Puskesmas immediately. Before, I would have just rested at home."

Similarly, a 41-year-old multigravida with a history of hypertension (P22, IDI-2) explained:

"The card is like a checklist in my bag. Every time I have an ANC visit, I look at the card. I check my blood pressure and I remember the danger signs. I feel more in control now. I'm not just waiting for something bad to happen I'm watching for it, and I know what to do."

Midwives corroborated these self-reported improvements. Midwife M04 (Puskesmas Hutaimbaru) noted:

"I can see the difference in our consultations. Before, patients would just nod when I talked about preeclampsia. Now they come with the card and ask questions: 'Bu Bidan, I checked this risk factor, what does it mean for me?' That's a big change. They are actively engaged."

The knowledge scores presented in Table 2 and Figure 1 provide quantitative corroboration of this thematic finding, with mean total knowledge improving from 47% to 84%.

Theme 2: The Smart Card as an Empowering and Accessible Educational Tool

The second major theme concerned participants' perceptions of the Smart Card itself as a medium for health education. Participants overwhelmingly praised the card's design

features, portability, and the manner in which it facilitated learning beyond the clinical encounter.

For participants with limited literacy, the pictorial elements of the card were particularly valued. A 45-year-old participant who had completed only primary education (P17, IDI-2) shared:

"I can't read the long words in the health booklet [Buku KIA], but the pictures on the card are easy to understand. The swollen hand picture I know that means swelling. The red heart I know that's about blood pressure. Even without reading, I understand."

A midwife (M06) reflected on this aspect:

"Many of our patients have low literacy. The card works because it doesn't rely on reading. The images are clear and culturally appropriate. I've seen patients who never open the Buku KIA studying the Smart Card."

The card's credit-card size enabled participants to carry it constantly, integrating it into their daily lives. A 26-year-old participant (P03, IDI-2) explained:

"I keep the card in my wallet, next to my BPJS card [health insurance card]. Every time I open my wallet, I see it. It's a constant reminder. I've also put it on my refrigerator at home with a magnet. My husband sees it too."

A notable and somewhat unexpected finding was the degree to which the Smart Card stimulated household-level health communication. Many participants reported sharing the card with their husbands and other family members, who subsequently became more involved in monitoring the pregnancy. A 28-year-old participant (P11, IDI-2) recounted:

"I showed the card to my husband. At first, he just glanced at it, but then he started asking questions: 'What is this sign? What should we do if this happens?' Now he helps me remember to check my blood pressure. He is more aware now. He takes it more seriously."

A 31-year-old participant living with her mother-in-law (P14, IDI-2) described:

"My mother-in-law was the one who always told me what to do in pregnancy, based on tradition. After I showed her the card, she was surprised. She said, 'I didn't know these things were serious.' Now she supports me going to the Puskesmas if I feel unwell."

This theme was also reflected in the FGDs. In FGD 2 (Puskesmas Sadabuan), one participant remarked, sparking a chorus of agreement:

"The card is not just for us it's for the whole family. My husband now asks, 'Did you check the card today?' It's become a family habit."

Theme 3: Empowerment in Health-Seeking Behavior

The third theme captured the behavioral consequences of improved knowledge and the Smart Card's role in fostering proactive health-seeking attitudes.

Participants reported that the Smart Card prompted more active engagement with their own health status during pregnancy. A 33-year-old obese participant (P07, IDI-2) stated:

"Before, I came to ANC, the midwife measured my blood pressure, and I waited to hear the number. Now I pay attention. I remember the threshold 140/90. If my pressure goes above that, I know I need to act."

Several participants described scenarios where their new knowledge led them to seek care earlier than they would have previously. A 27-year-old participant (P09, IDI-2) explained:

"Two weeks ago, I woke up with a headache that didn't go away after paracetamol. Normally, I would just stay in bed. But I looked at the card, and 'severe headache' was right there under danger signs. So I went to the Puskesmas the same day. My blood pressure was high, and they monitored me. The midwife said I did the right thing coming early."

The Smart Card also appeared to function as a communication bridge between patients and providers. A participant with tertiary education (P19, IDI-2) conveyed:

"Now I know the right words to use. I can tell the midwife: 'I'm worried about preeclampsia because I have this risk factor.' Before, I didn't know how to express my concerns. The card gave me a vocabulary for my own health."

Midwife M02 confirmed this observation:

"Patients are more articulate now. They mention specific symptoms and risk factors. This helps us provide better, more targeted counseling. It saves time and improves the quality of care."

Theme 4: Barriers, Challenges, and Contextual Limitations

While the overall findings were strongly positive, the analysis also identified several barriers and limitations that provide a more nuanced understanding of the intervention's real-world effectiveness.

Despite the card's visual design, some participants with very low literacy still struggled with certain elements. A 38-year-old participant who had never attended formal school (P24, IDI-2) shared:

"The pictures help, but I still had to ask my daughter to read the words on the back—'segera ke fasilitas kesehatan' [go to health facility immediately]. The words are small. Maybe they could make them bigger or add a picture of someone running to a clinic."

Several participants indicated that the card was most effective when initially introduced by a midwife who walked them through its contents. Self-study alone was insufficient for some. A 22-year-old primigravida (P06, IDI-2) explained:

"When the midwife first gave me the card and explained everything, it made sense. But when I tried to look at it alone at home, I wasn't sure if I was remembering correctly. I think the card works best when the midwife explains it first."

Midwife M05 noted:

"We need to remember that the card is a tool, not a replacement for counseling. The education session is essential. Without that initial guidance, some patients may misinterpret the icons or fail to appreciate the urgency of the danger signs."

Some participants highlighted that even with increased knowledge, structural barriers could impede timely health-seeking behavior. A participant from a low-income household (P16, IDI-2) stated:

"I understand now that I should go immediately if I have danger signs. But I live far from the Puskesmas, and I don't always have money for transportation. Knowing what to do is one thing; being able to do it is another."

This finding underscores that knowledge is a necessary but not sufficient condition for health behavior change; health system accessibility and social support remain critical enabling factors.

While the current study assessed knowledge at 4–6 weeks post-intervention, some participants expressed uncertainty about whether they would remember the information later in pregnancy or in a subsequent pregnancy. One participant from FGD 3 remarked:

"I know the signs now, but will I remember them when I'm in labor? Maybe the midwife should check with us at every ANC visit to refresh our memory."

Interviews with the 8 midwives provided additional insights that complemented and contextualized the pregnant women's narratives. Midwives unanimously endorsed the Smart Card as a useful educational adjunct but emphasized that its effectiveness depends on integration into routine ANC workflows.

Midwife M01 (Puskesmas Padangmatinggi) stated:

"The card has made my job easier. Instead of repeating the same information at every visit, I can use the card as a reference point. I ask the patient: 'Do you remember what this icon means?' It's interactive. It saves time and improves retention."

Midwife M03 raised the issue of scalability:

"If the government could produce these cards and distribute them through all Puskesmas, it would be a very effective program. But we need training for midwives on how to use the cards properly. Just handing out cards without explanation won't work."

Midwife M07 reflected on cultural sensitivity:

"The card uses simple Indonesian and generic images. For our local context, it works. But in some other areas with different cultural norms around pregnancy, the images might need to be adapted. For example, some communities may not recognize certain visual symbols."

Data saturation was achieved after 22 IDIs for the primary themes of knowledge transformation and tool acceptability. Variation continued to emerge in the barriers theme up to the 25th interview, particularly regarding literacy challenges and transportation access, justifying the inclusion of all 25 participants. No strongly deviant or negative cases were identified that fundamentally contradicted the central finding of intervention effectiveness, though the barriers theme provides important nuance to the overwhelmingly positive narratives.

The qualitative findings indicate that the Preeclampsia Risk Detection Smart Card intervention was effective in improving pregnant women's knowledge of preeclampsia risk factors, danger signs, and appropriate health-seeking behaviors in Padangsidimpuan City. The card's visual design, portability, and facilitation of household engagement were key mechanisms underlying its effectiveness. Barriers related to literacy, the need for facilitator guidance, and structural access constraints were identified as important considerations for future scale-up.

4. Discussion

The central finding of this study that the Smart Card intervention produced marked improvement in pregnant women's knowledge—is consistent with a substantial body of literature demonstrating the effectiveness of educational interventions targeting maternal health knowledge. The descriptive knowledge score improvement from 47% to 84% (a gain of 37 percentage points) who reported significant knowledge improvements following a Stunting Smart Card intervention (p=0.000), and with the broader systematic review which found universally positive effects of diverse educational modalities on knowledge of hypertensive disorders of pregnancy [11]

However, the contribution of the present study extends beyond mere confirmation of effectiveness. Through qualitative inquiry, we were able to illuminate how and why knowledge improvement occurred, revealing mechanisms that are not accessible through quantitative pre-post designs alone. Three interlinked mechanisms emerged. First, visual simplification transformed abstract medical concepts into concrete, recognizable symbols that bridged literacy gaps. For participants with limited education—who constitute a significant proportion of the pregnant population in Padangsidimpuan, as reflected in the 20% of participants with only primary education the pictorial representations of risk factors and danger signs rendered health information accessible in a way that text-based materials like the standard Buku KIA could not. This superiority of pictographic communication in health education for low-literacy populations and extends them to the specific domain of preeclampsia [12].

Second, continuous availability through portability transformed the Smart Card from a one-time educational input into a persistent environmental cue. The card, carried in participants' wallets or displayed on refrigerators, served as what behavioral economists term a "nudge" a subtle environmental prompt that keeps health considerations salient in daily life. This mechanism addresses a known limitation of traditional ANC-based education, in which information is delivered during brief consultations and may be

forgotten before the next visit, which may occur a month or more later. The 4–6-week follow-up period in this study demonstrated that knowledge was retained, consistent with the Tanzanian preeclampsia education study that documented knowledge retention at one month [13]

Third, and most significantly, the intervention activated social diffusion of health knowledge within households. The finding that pregnant women shared the Smart Card with husbands and mothers-in-law, who subsequently became more engaged in pregnancy monitoring, represents a potent amplification effect that has been underappreciated in the Smart Card literature. In the Indonesian kinship context, where pregnancy-related decisions are frequently made collectively rather than individually (particularly in Batak and Mandailing cultures where extended family involvement is normative), household engagement is not merely a desirable side effect but a potentially transformative mechanism for improving maternal outcomes. This finding resonates with Siti Jumhati's qualitative research in Pandeglang, which identified parents as the most frequent source of advice and input during pregnancy, and extends it by demonstrating that a well-designed educational tool can channel this influence in a medically appropriate direction rather than allowing it to default to traditional beliefs that may delay care-seeking [14].

The transformation from passive recipients of health information to active, questioning participants in their own care—evidenced by participants who now "come with the card and ask questions"—represents a shift toward what the World Health Organization terms "people-centered care," in which individuals are empowered to participate in decisions about their health (WHO, 2016). This empowerment effect, while challenging to quantify, may have long-term implications beyond the index pregnancy, as women who develop health literacy and self-advocacy skills during pregnancy may carry these capacities into future reproductive and general health encounters.

The Smart Card intervention possesses several distinctive features that differentiate it from other educational modalities evaluated in the literature. Compared to pamphlets, which are often text-heavy and may be discarded after a single reading, the laminated Smart Card is durable and reusable. Compared to mobile health (mHealth) applications, which hold great promise as demonstrated by the Ce'Dati intervention in Pandeglang—Smart Cards require no smartphone ownership, internet connectivity, or digital literacy, making them more equitable in settings where the digital divide persists. In Padangsidimpuan, where smartphone penetration is moderate but not universal, and where many women rely on husbands' phones if they access digital content at all, the physical card circumvents technological barriers entirely [15].

Compared to videos, PowerPoint presentations, or group education sessions, which require infrastructure, scheduling, and provider time, the Smart Card is instantly deployable and individually paced. A systematic review of educational interventions for preeclampsia concluded that a combination of modalities yields the best; in this light, the Smart Card should be understood not as a replacement for provider-led education but as a complement that extends the educational interaction beyond the clinical encounter.

The present study explicitly identified that the Smart Card works best when introduced through a structured education session with a midwife, rather than merely distributed. This finding is crucial for program design: it suggests that the card and the facilitator are co-dependent components of the intervention, and that efforts to scale up Smart Card distribution without investment in midwife training and protected education time may yield diminished returns. This is consistent with the implementation science principle that interventions are rarely effective when stripped of their implementation context and support structures.

The fourth theme—barriers, challenges, and limitations—provides essential balance to the predominantly positive findings and prevents an overly simplistic interpretation of

the intervention's effectiveness. The knowledge–behavior gap is a well-documented phenomenon in health promotion: increased knowledge does not automatically translate into behavior change when structural constraints (cost, distance, service availability) or social norms (gender dynamics, traditional beliefs) intervene.

The present study provides empirical examples of this gap. One participant explicitly stated that while she knew to seek care for danger signs, she lacked transportation money. This barrier is particularly relevant in Padangsidimpuan, where some Puskesmas catchment areas extend into semi-rural peripheries of the city. The National Health Insurance (JKN) scheme theoretically covers ANC and emergency obstetric care, but indirect costs (transportation, lost wages, childcare for other children) are not reimbursed and can be prohibitive for poor households.

The literacy barrier, despite the card's visual design, was not entirely overcome. This finding highlights the limits of pictographic communication and suggests that even well-designed visual materials may require supplementary support for the lowest-literacy users. The recommendation to increase font size and add a visual icon for "seek care immediately" is actionable and should be incorporated into future iterations of the card.

The expressed need for periodic refresher sessions at subsequent ANC visits aligns with the principles of spaced repetition in educational psychology, which holds that information is better retained when revisited at intervals over time. This suggests that the Smart Card intervention could be optimized through a "spiraling curriculum" approach in which the card content is reviewed briefly at each ANC contact, reinforcing key messages and checking comprehension.

The findings of this study carry several implications for maternal health practice and policy in Indonesia.

First, integration of Smart Card education into the ANC standard of care is recommended. The Indonesian Ministry of Health's current ANC guidelines do not specify a structured educational component for preeclampsia beyond routine blood pressure monitoring. The present study provides evidence that a low-cost, easily implemented educational intervention can significantly improve knowledge. Given that the Smart Card can be produced for approximately IDR 3,000–5,000 (USD 0.20–0.30) per unit at scale, the cost-effectiveness profile is potentially favorable. Formal health-economic evaluation is warranted.

Second, midwife training is essential. The study found that the card's effectiveness depended on the quality of the initial education session, which in turn depended on midwives' communication skills, knowledge of preeclampsia, and engagement with the intervention. A cascade training model training of trainers at the provincial level, followed by district-level workshops for Puskesmas midwives—could be implemented within existing professional development structures.

Third, adaptation for local contexts should be undertaken as the intervention is scaled. While the card used generic images that were acceptable in Padangsidimpuan, midwife feedback indicated that cultural adaptation of visual symbols may be necessary for implementation in other regions of Indonesia's diverse cultural landscape. Papua, for instance, has different visual semiotics than North Sumatra; what is intuitively recognizable in one cultural context may be ambiguous in another. A participatory design process involving local communities is recommended.

Fourth, the Smart Card approach could be extended to other maternal health topics such as postpartum hemorrhage, neonatal danger signs, and family planning, creating an integrated "Smart Card suite" for comprehensive maternal health education. The existing evidence base on Smart Cards for stunting and anemia, combined with the present findings on preeclampsia, suggests that the medium is versatile and broadly acceptable across health topics.

This study contributes to the theoretical understanding of health education in LMIC contexts by demonstrating the importance of what might be termed "household-mediated health education." Much of the existing health promotion literature focuses on individual-level knowledge change, with household or family involvement treated as a contextual variable or secondary outcome. Our finding that the Smart Card spontaneously activated spousal and intergenerational engagement—without this being an explicit objective of the intervention design—suggests that portable, visually accessible educational tools have an inherent capacity to bridge the individual–household divide in health communication. This has implications for the design of educational interventions beyond maternal health, including chronic disease management, where family support is a known determinant of adherence and outcomes.

The concept of "educational artifacts as environmental cues" also warrants further theoretical development. The Smart Card, by virtue of its physicality and portability, functioned as a persistent reminder that kept health information accessible and salient over time—a role that digital interventions (accessible only when a device is opened and an application is launched) may not replicate as effectively. In an era of enthusiasm for mHealth and eHealth solutions, the present study serves as a reminder that low-tech physical tools retain important advantages that should not be overlooked in the pursuit of technological sophistication.

5. Conclusion

This qualitative study provides robust evidence that the Preeclampsia Risk Detection Smart Card education intervention is effective in substantially improving pregnant women's knowledge of preeclampsia risk factors, danger signs, and appropriate health-seeking behaviors in Padangsidimpuan City, Indonesia. Through in-depth exploration of participants' lived experiences, the study identified four key mechanisms underlying the intervention's effectiveness: (1) visual simplification that overcomes literacy barriers and makes complex medical information accessible; (2) continuous availability through portability, which transforms the card into a persistent environmental cue; (3) facilitation of household-level health communication, with the card serving as a catalyst for spousal and intergenerational engagement in pregnancy monitoring; and (4) empowerment of pregnant women to adopt proactive, self-monitoring attitudes and to communicate more effectively with healthcare providers. The Smart Card represents a low-cost, culturally acceptable, and scalable educational tool that aligns with Indonesia's national priorities for reducing maternal mortality. However, the study also highlights that the intervention's effectiveness is contingent upon facilitator-led initial education, sensitivity to residual literacy challenges, and the adequacy of structural enablers such as transportation access and health service availability. Implementation at scale should therefore be accompanied by midwife training, contextual adaptation of visual materials, and integration with broader efforts to strengthen health system accessibility. The findings reinforce the message that innovative, context-sensitive health education—grounded in an understanding of local sociocultural dynamics, literacy constraints, and household decision-making patterns—can play a critical role in bridging the gap between clinical knowledge and community-level action, thereby contributing to the global effort to end preventable maternal deaths from preeclampsia.

6. Patents

This paper does not have a patent yet.

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Appendix A

Not appendix A

Appendix B

Not appendix B

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