

An AI and Wearable Technology-Enabled Smart School Framework for Early Depression Detection and Intervention Among High School Students

Rangka Kerja Sekolah Pintar Berkemampuan AI dan Teknologi Boleh Dipakai untuk Pengesanan dan Intervensi Kemurungan Awal dalam Kalangan Pelajar Sekolah Menengah

Rodziah Latih*, Chen Wangmei

Center for Software Technology and Management, Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi Selangor, Malaysia

*Corresponding author: Rodziah Latih (e-mail: rodziah.latih@ukm.edu.my)

ABSTRACT

Depression among adolescents has become a major global public health concern, significantly affecting academic performance, emotional well-being, and suicide risk. Conventional school-based depression screening methods primarily rely on questionnaires, interviews, and teacher observations, which are often resource-intensive, subjective, and unable to provide continuous monitoring. This study proposes an AI-enabled Smart School Framework that integrates wearable devices, the Internet of Things (IoT), artificial intelligence (AI), cloud computing, and behavioral analytics to enable early detection and intervention for depression among high school students. A systematic literature review following the PRISMA methodology was conducted to identify key indicators of depression, existing intervention strategies, and enabling smart-school technologies. Based on the findings, a five-layer framework was developed to support continuous monitoring, risk prediction, personalized intervention, and stakeholder collaboration involving students, teachers, counselors, and parents. The framework was evaluated through scenario-based analysis and expert feedback. The results indicate that the proposed framework has the potential to improve early detection accuracy, support timely intervention, reduce counselor workload, and enhance student mental health management. The study contributes a practical and scalable smart-school architecture for integrating emerging technologies into school-based mental health services. The framework was validated through scenario-based evaluation and expert review involving teachers and psychological counselors.

Keywords: Depression Detection, Smart School, Artificial Intelligence, Wearable Devices, Mental Health, Internet of Things

ABSTRAK

Kemurungan dalam kalangan remaja telah menjadi kebimbangan kesihatan awam global yang utama, yang menjejaskan prestasi akademik, kesejahteraan emosi dan risiko bunuh diri dengan ketara. Kaedah saringan kemurungan berasaskan sekolah konvensional terutamanya bergantung pada soal selidik, temu bual dan pemerhatian guru, yang selalunya memerlukan sumber yang intensif, subjektif dan tidak dapat menyediakan pemantauan berterusan. Kajian ini mencadangkan Rangka Kerja Sekolah Pintar yang didayakan AI yang mengintegrasikan peranti boleh pakai, Internet Pelbagai Benda (IoT), kecerdasan buatan (AI), pengkomputeran awan dan analitik tingkah laku untuk membolehkan pengesanan awal dan intervensi untuk kemurungan dalam kalangan pelajar sekolah menengah. Kajian literatur sistematik mengikut metodologi PRISMA telah dijalankan untuk mengenal pasti petunjuk utama kemurungan, strategi intervensi sedia ada dan mendayakan teknologi sekolah pintar. Berdasarkan dapatan kajian, rangka kerja lima lapisan telah dibangunkan untuk menyokong pemantauan berterusan, ramalan risiko, intervensi peribadi dan kerjasama pihak berkepentingan yang melibatkan pelajar, guru, kaunselor dan ibu bapa. Rangka kerja ini dinilai melalui analisis berasaskan senario dan maklum balas pakar. Keputusan menunjukkan bahawa rangka kerja yang dicadangkan berpotensi untuk meningkatkan ketepatan pengesanan awal, menyokong intervensi yang tepat pada masanya, mengurangkan beban kerja kaunselor dan mempertingkatkan pengurusan kesihatan mental pelajar. Kajian ini menyumbang kepada

seni bina sekolah pintar yang praktikal dan boleh diskala untuk mengintegrasikan teknologi baharu ke dalam perkhidmatan kesihatan mental berasaskan sekolah.

Kata kunci: Pengesanan Kemurungan, Sekolah Pintar, Kecerdasan Buatan, Peranti Boleh Pakai, Kesihatan Mental, Internet Pelbagai Benda

INTRODUCTION

Depression is one of the leading causes of illness, disability, and psychological distress among adolescents worldwide. Recent studies have reported increasing prevalence rates of depression among high school students, with symptoms ranging from persistent sadness, hopelessness, and loss of interest in daily activities to severe outcomes such as self-harm and suicidal ideation. Depression not only affects students' emotional well-being but also impairs academic performance, social relationships, cognitive functioning, and overall quality of life. If left undetected and untreated, depression may lead to long-term psychological consequences and increased suicide risk.

Despite growing awareness of adolescent mental health issues, current school-based depression detection approaches remain largely dependent on self-reported questionnaires, teacher observations, interviews, and counseling services. Common assessment instruments such as the Patient Health Questionnaire (PHQ-9), Center for Epidemiologic Studies Depression Scale (CES-D), and Depression Anxiety Stress Scale (DASS) have demonstrated good reliability and validity. However, these approaches are typically administered periodically and rely heavily on students' willingness to disclose their emotional states. As a result, early warning signs may be overlooked, monitoring is often discontinuous, and many at-risk students remain unidentified until their symptoms become severe. Furthermore, limited mental health resources and increasing student populations present additional challenges for schools in providing timely and effective support.

Recent advances in smart-school technologies provide new opportunities for addressing these challenges. Emerging technologies such as Artificial Intelligence (AI), wearable sensing devices, the Internet of Things (IoT), cloud computing, learning analytics, and big data analytics enable the continuous collection and analysis of behavioral, physiological, academic, and environmental data. These technologies offer the potential to support proactive mental health monitoring, early risk detection, personalized interventions, and real-time decision-making. However, existing studies have primarily focused on individual technologies or isolated applications and lack a comprehensive framework that integrates depression detection, risk assessment, intervention, and stakeholder collaboration within a smart-school ecosystem.

To address this gap, this study proposes an AI and Wearable Technology-Enabled Smart School Framework for Early Depression Detection and Intervention among High School Students. The framework integrates wearable devices, IoT infrastructure, student profile repositories, learning analytics, artificial intelligence, and stakeholder support mechanisms to create a holistic ecosystem for depression monitoring and management. The framework is designed to facilitate continuous data acquisition, identification of depression risk factors, risk assessment and classification, personalized intervention, and collaborative support involving students, teachers, counselors, parents, school administrators, and mental health professionals.

The objectives of this study are threefold: (1) to identify key indicators and risk factors associated with depression among high school students through a systematic literature review; (2) to develop a smart-school framework that supports continuous depression monitoring, risk assessment, and intervention; and (3) to evaluate the feasibility and practicality of the proposed framework through scenario-based analysis and expert validation.

This study makes five main contributions. First, it proposes a comprehensive smart-school framework for early depression detection and intervention. Second, it introduces a six-dimensional depression risk factor model comprising academic, behavioral, sleep, social, family, and psychological factors. Third, it develops a depression risk assessment and classification mechanism for identifying students at different

levels of depression risk. Fourth, it integrates AI, wearable technologies, and stakeholder collaboration into a unified architecture for school-based mental health management. Finally, it provides expert validation of the proposed framework and demonstrates its potential applicability in smart-school environments.

Unlike existing studies that focus on isolated technologies or individual depression indicators, this study proposes an integrated smart-school framework that combines continuous monitoring, risk assessment, intervention, and stakeholder collaboration within a single architecture.

RELATED WORKS

Depression Among High School Students

Depression is one of the most prevalent mental health disorders among adolescents and has become a growing public health concern worldwide (Shorey et al., 2022; Fonseca-Pedrero et al., 2023). Numerous studies have reported moderate to severe levels of depression among high school students across different countries and educational settings. Depression can negatively affect students' academic performance, social relationships, emotional well-being, and overall quality of life. Common symptoms include persistent sadness, suicidal ideation, sleep disturbances, fatigue, lack of motivation, poor concentration, declining academic performance, and feelings of hopelessness (Zhang et al., 2022; Zhang et al., 2023). If left untreated, depression may lead to self-harm, substance abuse, school dropout, and suicide. Consequently, early identification and timely intervention are critical for reducing the long-term impact of depression on adolescent development.

Depression Detection Approaches

Various methods have been developed to identify depression among adolescents. Conventional approaches primarily rely on self-reported questionnaires, interviews, teacher observations, and psychological assessments. Commonly used instruments include the Patient Health Questionnaire (PHQ-9), the Center for Epidemiologic Studies Depression Scale (CES-D), and the Depression Anxiety Stress Scale (DASS) (Zhang et al., 2023). These instruments have demonstrated strong reliability and validity in measuring depression symptoms. However, they are typically administered periodically and depend heavily on self-disclosure, which may limit their effectiveness in identifying students who are unwilling or unable to communicate their emotional conditions.

Recent studies have explored data-driven approaches for depression detection by analyzing behavioral, academic, and physiological indicators. Attendance records, academic performance, classroom participation, social interactions, sleep patterns, and online activities have been investigated as potential predictors of depression. These approaches provide opportunities for earlier detection and continuous monitoring compared with traditional assessment methods.

Smart School Technologies

The emergence of smart-school technologies has created new opportunities for supporting student mental health. Advances in Artificial Intelligence (AI), the Internet of Things (IoT), wearable devices, cloud computing, learning analytics, and computer vision enable the collection and analysis of large volumes of educational and behavioral data (Aceto et al., 2020; Kaywan et al., 2023). Wearable devices can monitor sleep quality, physical activity, heart rate, and other physiological indicators associated with depression (Eid et al., 2023; Mahariya et al., 2023). AI-based systems can analyze attendance patterns, classroom participation, facial expressions, and academic performance trends to identify students who may be at risk.

In addition, smart-school infrastructures support continuous monitoring, automated alerts, personalized recommendations, and real-time intervention. These capabilities allow educational institutions to move from reactive approaches toward proactive and preventive mental health management. Nevertheless, most existing studies focus on individual technologies or specific use cases rather than providing an integrated framework that combines data collection, risk assessment, intervention, and stakeholder collaboration.

Theoretical Foundation

The proposed framework is informed by several complementary theoretical perspectives. First, Ecological Systems Theory suggests that adolescent mental health is influenced by multiple interconnected environments, including individual characteristics, family relationships, peer interactions, and school experiences. This perspective supports the inclusion of academic, behavioral, social, family, sleep, and psychological factors within the framework.

Second, Learning Analytics theory emphasizes the use of educational data to understand student behavior and support data-driven decision-making. This theory provides the foundation for collecting and analyzing multimodal student data to identify risk patterns and generate early warnings. Third, Early Warning Systems advocate continuous monitoring and risk classification to enable timely intervention before problems become severe. Finally, mental health intervention models emphasize the importance of coordinated support involving students, teachers, counselors, parents, and healthcare professionals.

Together, these theoretical perspectives provide the conceptual foundation for the proposed AI and Wearable Technology-Enabled Smart School Framework. They also address a significant research gap in the literature, as existing studies generally focus on isolated technologies rather than a comprehensive school-wide framework that integrates depression detection, risk assessment, intervention, and stakeholder collaboration.

METHODOLOGY

This study adopted a five-stage research methodology consisting of (1) systematic literature review, (2) identification of depression indicators, (3) analysis of intervention strategies and enabling technologies, (4) framework development, and (5) framework evaluation. The overall research process is illustrated in Figure 1.

Systematic Literature Review

A systematic literature review (SLR) was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to identify key indicators of depression, intervention strategies, implementation challenges, and emerging technologies relevant to the detection and prevention of depression among high school students (Page et al., 2021). Publications published between 2019 and 2023 were retrieved from major academic databases, including Scopus, Web of Science, ScienceDirect, IEEE Xplore, and Google Scholar.

The primary search terms included “depression”, “adolescent depression”, “high school students”, “mental health”, “depression intervention”, and “depression prevention”. To ensure the quality and relevance of the reviewed studies, the following exclusion criteria were applied: (a) non-journal and non-conference publications, (b) incomplete or non-final publications, (c) non-English articles, (d) inaccessible full-text publications, (e) studies unrelated to depression among high school students, and (f) studies focusing exclusively on a single gender. Following the screening and eligibility assessment process, a total of 139 publications were selected for detailed analysis, as illustrated in Figure 1.

Identification of Depression Indicators

The selected studies were systematically analyzed to identify the most frequently reported indicators associated with adolescent depression. Seven major indicators were identified: suicidal ideation and self-harm behavior, sleep disturbances, lack of interest and participation, fatigue and concentration difficulties, declining academic performance, feelings of hopelessness, and persistent low mood. These indicators were subsequently used as the foundation for developing the proposed depression risk assessment framework.

Analysis of Intervention Strategies and Enabling Technologies

The literature review also examined existing intervention and prevention approaches for adolescent depression. Among the 139 selected studies, 40 publications explicitly discussed intervention strategies. The findings revealed six commonly recommended approaches: (1) teacher, parent, and school support;

(2) psychotherapy and counseling; (3) regular exercise and extracurricular activities; (4) sleep-related interventions; (5) medication and nutritional support; and (6) mobile phone usage management. In addition, several studies highlighted the importance of improving school facilities, safety measures, and learning environments to support students' mental well-being.

The review further identified four major challenges that limit the effectiveness of existing depression prevention and intervention initiatives: the lack of effective detection methods, bullying and social stigma, limited mental health resources, and difficulties in large-scale implementation. These findings informed the design requirements of the proposed framework.

In parallel, the review investigated emerging technologies that could support smart-school mental health monitoring and intervention. The identified technologies include Artificial Intelligence (AI), the Internet of Things (IoT), wearable devices, cloud computing, big data analytics, learning analytics, computer vision, and mobile applications (Matheshwaran et al., 2025; Varje et al., 2026; LaBoone & Marques, 2024; Boujmiraz et al., 2026). These technologies were mapped to the identified depression indicators and intervention requirements to establish the technological foundation of the framework.

Framework Development

Based on the findings of the systematic literature review, a conceptual framework was developed to support early detection and intervention for depression in smart school environments. The framework integrates multimodal data acquisition, depression risk factors, risk assessment and classification mechanisms, intervention services, and stakeholder collaboration into a unified architecture. The design emphasizes continuous monitoring, proactive intervention, and coordinated support among students, teachers, counselors, parents, and external mental health professionals.

Framework Evaluation

The proposed framework was evaluated using a combination of scenario-based usability analysis and expert validation. Three representative scenarios—depression detection, suicide prevention, and insomnia monitoring—were developed to assess the practical applicability of the framework in real school settings. In addition, semi-structured interviews were conducted with five experts, comprising three high school homeroom teachers and two psychological counselors, to evaluate the framework in terms of technological innovation, automation capability, user satisfaction, and sustainability. The evaluation results were used to refine the framework and assess its feasibility for deployment in smart school environments.

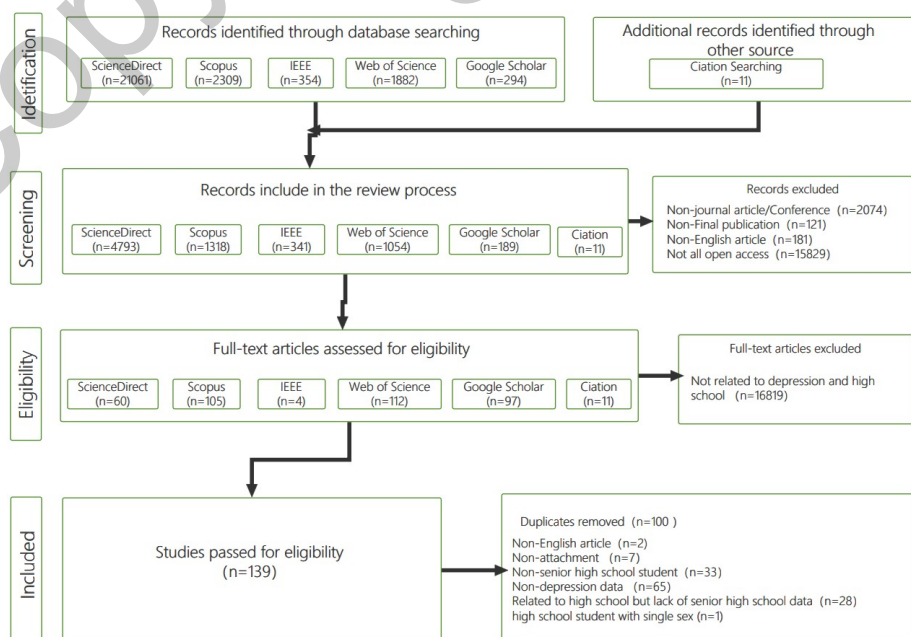


FIGURE 1. Study Flow Diagram from PRISMA for Depression in High School.

PROPOSED FRAMEWORK

The proposed AI and Wearable Technology-Enabled Smart School Framework for Early Depression Detection and Intervention comprises five interconnected layers that collectively support continuous monitoring, early identification, risk assessment, and timely intervention for students who may be vulnerable to depression. The framework integrates smart-school technologies, wearable sensing devices, learning analytics, and mental health support services to provide a comprehensive and proactive approach to student well-being.

The first layer, the Data Acquisition Layer, serves as the foundation of the framework by continuously gathering multimodal data from diverse sources within the smart-school ecosystem. These sources include a Student Profile Repository containing demographic, family, parental, academic, and health-related information, as well as wearable devices, attendance management systems, learning management systems (LMS), academic records, classroom monitoring systems, environmental sensors, psychological screening instruments, and student support records. By consolidating data from multiple domains, the framework establishes a holistic representation of each student's educational, behavioral, social, physical, and psychological profile.

The second layer, the Depression Risk Factors Layer, transforms the collected data into six key dimensions that are widely recognized in the literature as significant determinants of adolescent depression. These dimensions comprise Academic Factors, Behavioral Factors, Sleep Factors, Social Factors, Family Factors, and Psychological Factors. Together, these dimensions provide a structured mechanism for identifying risk patterns and understanding the multifaceted nature of depression among high school students.

The third layer, the Depression Risk Assessment and Classification Layer, functions as the analytical core of the framework. Information derived from the six risk dimensions is integrated and processed by a Depression Risk Assessment Engine that performs data preprocessing, feature extraction, multi-factor analysis, risk scoring, and early warning generation. Based on the calculated risk scores, students are classified into four categories—Low Risk, Moderate Risk, High Risk, and Critical Risk—allowing schools to identify vulnerable students and prioritize intervention efforts according to the severity of their risk profiles.

The fourth layer, the Intervention Layer, provides personalized and evidence-based responses tailored to students' risk levels. Intervention strategies include automated alerts, counseling referrals, parent notifications, personalized recommendations, AI chatbot support, Cognitive Behavioral Therapy (CBT)-based resources, and crisis management services for high-risk cases. This layer aims not only to address existing mental health concerns but also to support prevention, early intervention, and long-term well-being.

The fifth layer, the Stakeholder Support and Collaboration Layer, promotes coordinated participation among students, teachers, counselors, psychologists, parents, school administrators, and external mental health professionals. Through collaborative decision-making and continuous communication, stakeholders can monitor student progress, deliver appropriate support, and ensure the effective implementation of intervention plans.

To ensure sustainability and continuous improvement, the framework incorporates a feedback mechanism that channels intervention outcomes, updated student information, and newly acquired data back into the Data Acquisition Layer. This cyclical process enables continuous monitoring, refinement of risk assessment models, and enhancement of intervention effectiveness over time.

In addition, security, privacy, and governance principles are embedded throughout all layers of the framework through data encryption, access control, anonymization, consent management, auditing, and regulatory compliance measures. These safeguards ensure the ethical and responsible use of sensitive student information while maintaining trust among all stakeholders. Figure 2 below shows the AI and Wearable Technology-Enabled Smart School Framework. Data collected through smart-school infrastructure are transformed into six depression risk dimensions, processed by the Depression Risk

Assessment Engine, classified into risk levels, and subsequently linked to personalized intervention and stakeholder collaboration mechanisms.



FIGURE 2. Proposed AI and Wearable Technology-Enabled Smart School Framework for Early Depression Detection and Intervention Among High School Students.

ETHICAL AND PRIVACY CONSIDERATIONS

The implementation of AI-enabled depression detection systems in educational environments raises important ethical, privacy, and governance concerns due to the sensitive nature of students' mental health data. Therefore, ethical safeguards must be incorporated throughout the framework to ensure responsible data collection, analysis, and intervention.

First, informed consent should be obtained from both students and their parents or legal guardians before any personal, behavioral, or physiological data are collected. Participants should be clearly informed about the purpose of data collection, the types of data being monitored, how the data will be used, and their rights regarding participation and data access.

Second, robust data protection mechanisms are essential to safeguard sensitive information. All collected data should be encrypted during transmission and storage, anonymized whenever possible, and protected through role-based access control to ensure that only authorized personnel can access student records. Compliance with relevant privacy regulations and institutional policies should also be maintained.

Third, the framework must address potential bias in AI-based decision-making. Machine learning models may inadvertently produce inaccurate or unfair predictions due to biased training data, demographic imbalances, or algorithmic limitations. Regular auditing, model validation, and fairness assessments should therefore be conducted to minimize bias and improve the reliability of risk assessments across diverse student populations.

Finally, human oversight must remain an integral component of the framework. AI-generated risk scores and recommendations should serve as decision-support tools rather than replacements for professional judgment. Teachers, counselors, psychologists, and other qualified personnel should review assessment outcomes and determine appropriate interventions. This human-in-the-loop approach helps reduce the risk of misclassification, ensures contextual understanding of student circumstances, and promotes ethical decision-making in mental health support.

By incorporating informed consent, data protection, bias mitigation, and human oversight mechanisms, the proposed framework seeks to balance technological innovation with ethical responsibility, privacy preservation, and student well-being.

EVALUATION AND DISCUSSION

The proposed framework was evaluated using a two-stage approach comprising scenario-based usability evaluation and expert validation. The objective of the evaluation was to assess the feasibility, practicality, and potential effectiveness of the framework in supporting early depression detection and intervention within smart school environments.

Three representative scenarios were selected to demonstrate the framework's practical application: (1) depression detection, (2) suicide prevention, and (3) insomnia monitoring. These scenarios were chosen because depression symptoms, suicidal behavior, and sleep disturbances are consistently reported in the literature as major indicators of adolescent depression.

To further assess the framework, semi-structured interviews were conducted with five experts from different regions of China, including three high school homeroom teachers and two psychological counselors. The evaluation focused on four key dimensions: technological innovation, automation capability, user satisfaction, and system sustainability.

Scenario-Based Evaluation

The first scenario evaluated the framework's ability to detect students at risk of depression by integrating multiple data sources, including attendance records, academic performance, activity participation, homework completion, sleep patterns, teacher observations, and chatbot interactions. The framework successfully demonstrated how risk-related indicators can be aggregated and analyzed to generate early warnings for teachers and counselors, enabling timely intervention and support.

The second scenario examined the framework's capability to support suicide prevention. By integrating access-control systems, facial recognition technologies, and computer vision-based monitoring, the framework was able to identify abnormal behaviors in high-risk locations and generate real-time alerts for school personnel. This scenario demonstrated the framework's potential to facilitate proactive intervention before critical incidents occur.

The third scenario focused on insomnia monitoring. Wearable device data, dormitory access records, and mobile device usage information were utilized to identify abnormal sleep patterns. The scenario illustrated how sleep-related indicators can be continuously monitored and used as an early warning mechanism for assessing depression risk.

Overall, the scenario-based evaluation demonstrated the practicality of integrating multiple data sources and smart technologies to support continuous monitoring and early intervention in school environments.

Expert Validation Results

The expert validation results indicate positive perceptions of the proposed framework across all evaluation dimensions. Table 1 summarizes the overall findings.

TABLE 1. Summary of Expert Validation Results.

Evaluation Dimension	Key Findings	Recommendations
Technological Innovation	Experts agreed that the framework is innovative and leverages AI, wearable devices, and smart-school technologies to support depression detection and intervention.	Add real-time communication mechanisms for emergency situations and refine mobile phone monitoring to focus on sleep periods.
Automation	Experts agreed that the framework can	Further testing is needed to verify the

Capability	automatically identify depression risks and generate timely alerts for intervention.	accuracy of the assessment engine.
User Satisfaction	Experts agreed that the framework meets the needs of students, teachers, and counselors.	Increase parental awareness and support while protecting students' privacy.
System Sustainability	Experts acknowledged the framework's potential but highlighted challenges in cost, infrastructure, and implementation.	Conduct pilot implementations, seek government and institutional support, provide teacher training, and design user-friendly interfaces to facilitate adoption and long-term sustainability.
Overall Assessment	Experts considered the framework feasible, innovative, and promising.	Further empirical validation, prototype development, and large-scale pilot studies are required before practical deployment.

All experts agreed that the framework represents an innovative approach to school-based depression detection and prevention. The integration of wearable technologies, artificial intelligence, learning analytics, and smart-school infrastructure was considered valuable for enabling continuous monitoring and shifting mental health management from a reactive to a proactive process.

Regarding automation capability, experts highlighted the framework's ability to automatically identify risk patterns, monitor student behaviors, and generate timely alerts for teachers and counselors. However, they emphasized the need for future empirical validation to ensure that the depression risk assessment mechanism achieves acceptable levels of accuracy and reliability when compared with clinical diagnoses.

In terms of user satisfaction, experts acknowledged the potential benefits of the framework for students, teachers, and counselors. They particularly emphasized the importance of parental involvement and recommended additional mechanisms to increase parents' awareness of depression and strengthen family support for at-risk students.

Although experts recognized the long-term value of the framework, sustainability received a moderate assessment due to concerns regarding implementation costs, technological infrastructure requirements, organizational readiness, and stakeholder acceptance. Several experts recommended pilot implementations, government-supported initiatives, and comprehensive teacher training programs to improve adoption and long-term sustainability.

Discussion

The evaluation results suggest that the proposed framework is a feasible and promising approach for supporting early depression detection and intervention in smart school environments. Compared with traditional questionnaire-based screening methods, the framework leverages continuous monitoring and multimodal data integration to provide a more comprehensive understanding of student well-being. Furthermore, the incorporation of automated alerts and stakeholder collaboration mechanisms enables earlier identification of at-risk students and facilitates more timely intervention.

Despite these promising findings, several limitations should be acknowledged. First, the framework remains conceptual and has not yet been implemented as a functional prototype. Second, the evaluation used scenario analysis and interviews with a relatively small number of experts, which may limit the generalizability of the findings. Third, the accuracy and reliability of the proposed Depression Risk Assessment Engine have not yet been validated using real-world student data. Finally, practical challenges related to privacy protection, ethical considerations, implementation costs, and stakeholder acceptance require further investigation before large-scale deployment.

Future research should focus on developing a functional prototype, validating the risk assessment model using real-world datasets, conducting pilot implementations in educational institutions, and evaluating the framework's effectiveness through longitudinal studies. Such efforts will provide stronger empirical

evidence regarding the framework's capability to support student mental health management in smart school environments.

Overall, the evaluation indicates that the proposed framework has substantial potential to enhance mental health monitoring, support early intervention, and strengthen collaboration among students, teachers, counselors, parents, and external mental health professionals.

CONCLUSION

Depression among high school students is a growing concern that can negatively affect academic performance, emotional well-being, social relationships, and overall quality of life. Conventional depression screening methods are often limited by their reliance on periodic assessments, self-reported questionnaires, and manual observation, making early identification and intervention challenging. To address these limitations, this study proposed an AI and Wearable Technology-Enabled Smart School Framework for early depression detection and intervention.

The proposed framework integrates wearable devices, the Internet of Things (IoT), artificial intelligence, cloud computing, learning analytics, and mental health support services to enable continuous monitoring, risk assessment, and personalized intervention. By combining data from multiple sources and organizing them into six depression risk dimensions—academic, behavioral, sleep, social, family, and psychological factors—the framework provides a comprehensive approach to identifying students who may be at risk of depression. Furthermore, the framework supports coordinated intervention through collaboration among students, teachers, counselors, parents, school administrators, and external mental health professionals.

This study makes five key contributions. First, it proposes a comprehensive smart-school framework for early depression detection and intervention. Second, it introduces a six-dimensional depression risk factor model that captures the multifaceted nature of adolescent depression. Third, it presents a depression risk assessment and classification mechanism for identifying different levels of risk. Fourth, it establishes a stakeholder support and collaboration model to facilitate coordinated mental health management within school environments. Finally, it provides an expert-validated conceptual architecture that demonstrates the feasibility and potential value of integrating AI and wearable technologies into school-based mental health services.

The evaluation results indicate that the proposed framework is practical, innovative, and capable of supporting proactive depression monitoring and intervention. However, several limitations should be acknowledged. The framework remains conceptual and has not yet been implemented as a functional prototype. The validation was conducted using a limited number of expert interviews, and no real-world student data were used to assess the accuracy of the proposed risk assessment mechanism. In addition, issues related to privacy, data governance, implementation cost, and stakeholder acceptance require further investigation before large-scale deployment.

Future research will focus on developing a functional prototype of the framework, designing and validating machine learning models for depression risk prediction, and conducting large-scale pilot studies in real educational settings. Further work will also examine the accuracy, reliability, usability, and ethical implications of the framework to ensure its effectiveness and sustainability in supporting student mental health and well-being.

REFERENCES

- Aceto, G., Persico, V., & Pescapé, A. 2020. Industry 4.0 and health: Internet of things, big data, and cloud computing for healthcare 4.0, *Journal of Industrial Information Integration* 18 (2020): 100129. doi:10.1016/j.jii.2020.100129
- Boujmiraz, S., Darhmaoui, H., & Drissi El Maliani, A. 2026. Predicting student performance: A comprehensive review of machine learning, deep learning, and explainable AI approaches,

- Computers and Education: Artificial Intelligence* 10 (2026): 100548. doi:10.1016/j.caeai.2026.100548
- Eid, M. M., Yundong, W., Mensah, G. B., & Pudasaini, P. 2023. Treating psychological depression utilising artificial intelligence: AI for precision medicine—Focus on procedures, *Mesopotamian Journal of Artificial Intelligence in Healthcare* 2023 (2023): 76–81. doi:10.58496/MJAIH/2023/015
- Fonseca-Pedrero, E., Díez-Gómez, A., Pérez-Albéniz, A., Al-Halabí, S., Lucas-Molina, B., & Debbané, M. 2023. Youth screening depression: Validation of the Patient Health Questionnaire-9 (PHQ-9) in a representative sample of adolescents, *Psychiatry Research* 328 (2023): 115486. doi:10.1016/j.psychres.2023.115486
- Kaywan, P., Ahmed, K., Ibaida, A., Miao, Y., & Gu, B. 2023. Early detection of depression using a conversational AI bot: A non-clinical trial, *PLOS ONE* 18, No. 2 (2023). doi:10.1371/journal.pone.0279743
- LaBoone, P. A., & Marques, O. 2024. Overview of the future impact of wearables and artificial intelligence in healthcare workflows and technology, *International Journal of Information Management Data Insights* 4, No. 2 (2024): 100294. doi:10.1016/j.jjimei.2024.100294
- Mahariya, S. K., Kumar, A., Singh, R., Gehlot, A., Akram, S. V., Twala, B., Iqbal, M. I., & Priyadarshi, N. 2023. Smart school 4.0: Digitalization of university school with assimilation of Industry 4.0 for innovation and sustainability, *Journal of Advanced Research in Applied Sciences and Engineering Technology* 32, No. 1 (2023): 120–138. doi:10.37934/araset.32.1.120138
- Matheshwaran, M., Makeswar, K., Sahul Hameed Muhammed, S., & Vincent Antony Kumar, A. 2025. AI-integrated biometric attendance and health monitoring system, *International Journal of Innovative Research in Technology* 11, No. 12 (2025).
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. 2021. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews, *PLOS Medicine* 18, No. 3 (2021): e1003583. doi:10.1371/journal.pmed.1003583
- Shorey, S., Ng, E. D., & Wong, C. H. J. 2022. Global prevalence of depression and elevated depressive symptoms among adolescents: A systematic review and meta-analysis, *British Journal of Clinical Psychology* 61, No. 2 (2022): 287–305. doi:10.1111/bjc.12333
- Varje, P., Väänänen, A., Haavisto, O., Kivimäki, I., Taimela, S., & Kalliomäki-Levanto, T. 2026. Machine learning in the analysis of mental health at work: A scoping review, *Open Access Journal of Occupational Health* 68, No. 1 (2026). doi:10.1093/joccuh/uiag014
- Zhang, J., Liu, D., Ding, L., & Du, G. 2023. Prevalence of depression in junior and senior adolescents, *Frontiers in Psychiatry* 14 (2023). doi:10.3389/fpsy.2023.1182024
- Zhang, Xiaozhi, Yan, Y., Ye, Z., & Xie, J. 2023. Descriptive analysis of depression among adolescents in Huangshi, China, *BMC Psychiatry* 23, No. 1 (2023): 176. doi:10.1186/s12888-023-04682-3
- Zhang, Xin, Gao, F., Kang, Z., Zhou, H., Zhang, J., Li, J., Yan, J., Wang, J., Liu, H., Wu, Q., & Liu, B. 2022. Perceived academic stress and depression: The mediation role of mobile phone addiction and sleep quality, *Frontiers in Public Health* 10 (2022): 760387. doi:10.3389/fpubh.2022.760387