

ORIGINAL RESEARCH

Development and evaluation of an AI-enabled dual-mentor psychological support closed-loop system for nursing interns: A quasi-experimental study

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Received: February 9, 2026

Accepted: April 2, 2026

Online Published: April 28, 2026

DOI: 10.63564/jnep.v16n5p41

URL: <https://doi.org/10.63564/jnep.v16n5p41>

ABSTRACT

Background and objective: Nursing interns frequently experience psychological distress during clinical training, which may negatively affect learning outcomes and professional development. Traditional dual-mentor models provide important educational support but often lack continuous monitoring of interns' psychological status. This study aimed to develop and evaluate an AI-enabled dual-mentor psychological support closed-loop system and to examine its effects on nursing interns' clinical skills, emotional exhaustion, and internship satisfaction.

Methods: A quasi-experimental pretest–posttest control group design was adopted. A total of 200 nursing interns from a vocational college in Zhejiang Province, China, were assigned to an experimental group (n = 100) or a control group (n = 100) using cluster sampling. The experimental group received an AI-enabled dual-mentor psychological support intervention in addition to routine internship supervision for one semester, while the control group received routine dual-mentor supervision only. Outcomes included clinical skills performance, emotional exhaustion (MBI-GS), and internship satisfaction. Data were analyzed using paired *t*-tests, chi-square tests, and analysis of covariance (ANCOVA).

Results: The proportion of interns achieving excellent clinical skills performance was significantly higher in the experimental group than in the control group (28.0% vs. 11.0%, $\chi^2 = 9.82$, $p = .002$). After controlling for baseline scores, the experimental group reported significantly lower posttest emotional exhaustion ($F = 25.34$, $p < .001$) and significantly higher internship satisfaction than the control group ($F = 18.56$, $p = .008$).

Conclusions: The AI-enabled dual-mentor psychological support closed-loop system effectively improves nursing interns' clinical skills, reduces emotional exhaustion, and enhances internship satisfaction. The system was particularly effective in identifying early signs of psychological distress and facilitating timely, tiered interventions, serving as a supportive tool that enhances—rather than replaces—the established dual-mentor framework.

Key Words: Artificial intelligence, Closed-loop system, Dual-mentor system, Nursing interns, Psychological support

1. INTRODUCTION

Nursing internship represents a critical stage in the transition from student to professional nurse and plays an essential role in the development of clinical competence and professional identity. During this period, nursing interns are required to adapt to complex clinical environments, assume

increasing responsibilities, and apply theoretical knowledge to real-world practice. These demands often place substantial psychological pressure on interns and may lead to emotional distress, anxiety, and burnout, which in turn negatively influence learning effectiveness, clinical performance, and career commitment.^[1,2] Previous research has shown that nurs-

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ing interns commonly experience role transition difficulties, heavy workloads, and psychological stress, which are associated with increased emotional exhaustion and poorer learning outcomes.^[3,4]

Emotional exhaustion is considered one of the core dimensions of burnout among nursing students and newly graduated nurses. High levels of emotional exhaustion are associated with decreased motivation, impaired concentration, and reduced quality of patient care.^[5] Therefore, providing timely and effective psychological support during internship is essential for promoting both mental well-being and professional development among nursing interns.

The dual-mentor system, typically involving a school-based mentor and a clinical mentor, has been widely implemented in nursing education to support students' learning and professional socialization. This model enables nursing interns to receive guidance from both academic and clinical perspectives and has demonstrated positive effects on skill acquisition and role adaptation.^[6] Moreover, dual-mentor models integrating academic and clinical supervision have been shown to improve students' learning experiences and professional development.^[7,8] However, traditional dual-mentor approaches often rely on periodic communication and subjective observation, which may limit mentors' ability to continuously monitor interns' psychological status and to identify early signs of distress.

With the rapid development of artificial intelligence (AI) technologies, new opportunities have emerged for enhancing psychological support in educational contexts.^[9,10] AI-based techniques such as emotion analysis, behavioral data mining, and intelligent alert systems enable continuous monitoring of learners' psychological states and facilitate timely, personalized interventions. In nursing education, preliminary studies suggest that AI-supported platforms may improve learning engagement and provide individualized support.^[11,12] Nevertheless, most existing research has focused on single-function applications or conceptual frameworks, and empirical evidence regarding integrated AI-enabled psychological support systems within internship training remains limited.

To address these gaps, this study aimed to develop and evaluate an AI-enabled dual-mentor psychological support closed-loop system and examine its effects on nursing interns' clinical skills, emotional exhaustion, and internship satisfaction.

2. METHODS

2.1 Study design

A quasi-experimental pretest–posttest control group design was employed to examine the effects of an AI-enabled dual-

mentor psychological support closed-loop system on nursing interns' professional skills, emotional exhaustion, and internship satisfaction.

2.2 Participants and setting

Participants were nursing students from a vocational college in Zhejiang Province, China, who began their clinical internships at Wenzhou People's Hospital and the Affiliated Hospital of Zhejiang Dongfang Polytechnic in July 2025.

Inclusion criteria were:

- (1) first-time participation in clinical internship;
- (2) willingness to participate in the study and provision of written informed consent.

Exclusion criteria were:

- (1) history of diagnosed psychiatric disorders;
- (2) interruption of internship for more than two weeks during the study period.

Using cluster sampling, four internship groups were assigned to the experimental group ($n = 100$), and four comparable internship groups were assigned to the control group ($n = 100$). No significant differences were found between the two groups in age, gender, academic performance, or baseline outcome measures ($p > .05$), indicating baseline comparability.

2.3 Intervention

Both groups received routine dual-mentor supervision, consisting of biweekly offline clinical rounds and monthly online progress reviews. The experimental group received an AI-enabled dual-mentor psychological support intervention in addition to routine internship supervision for one semester (July–December 2025). The control group received routine dual-mentor supervision only.

The intervention was implemented on the Gongxueyun platform and consisted of four integrated functional modules: data collection and monitoring, AI-based psychological monitoring and risk alert, tiered response, and feedback and optimization. The overall system architecture and operational workflow of the AI-enabled dual-mentor psychological support closed-loop system are illustrated in Figure 1. As shown in Figure 1, the system operates through four sequential modules: data collection establishes the foundation for AI-based psychological monitoring, which generates risk alerts and triggers tiered responses, while feedback and optimization ensure continuous system improvement.

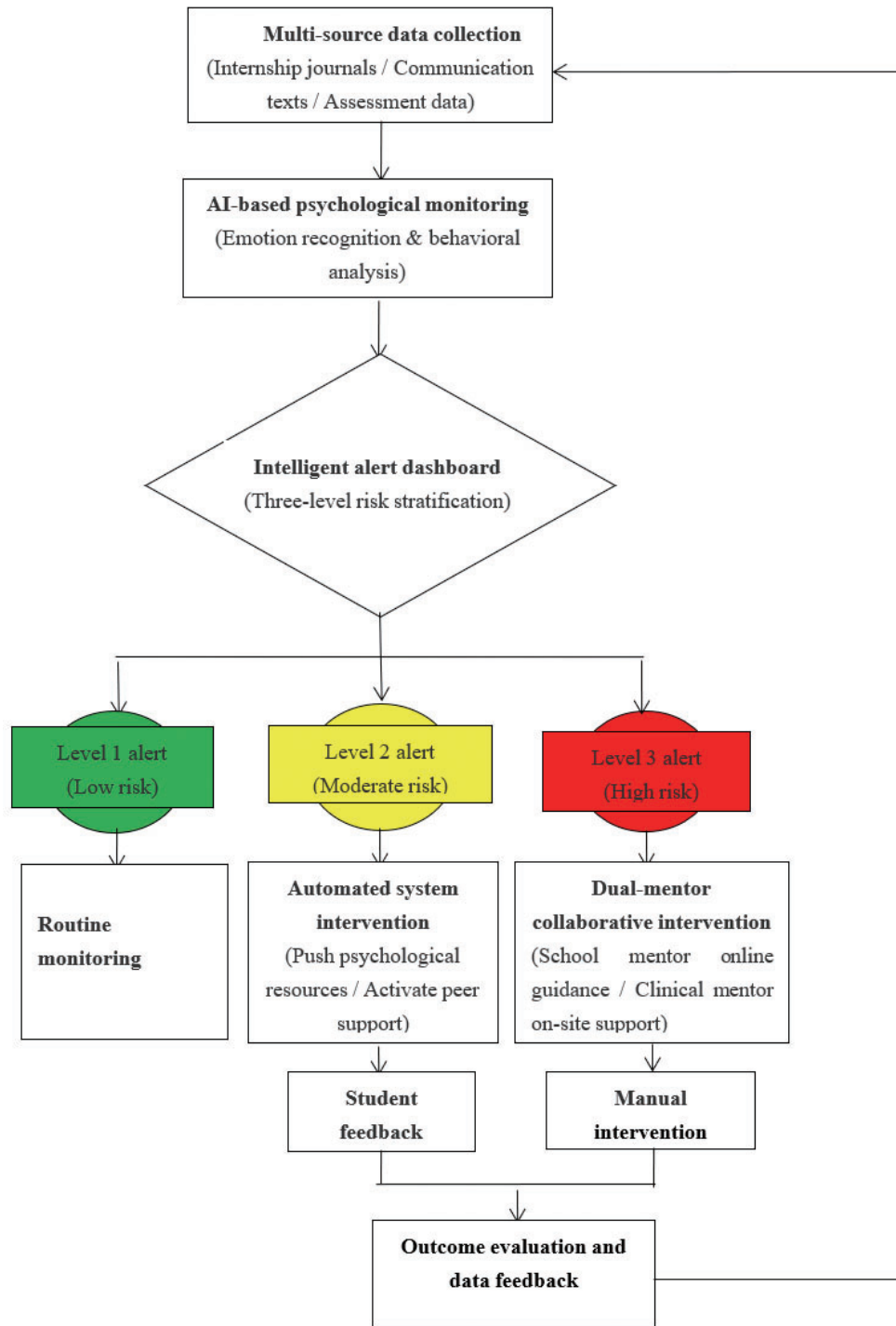


Figure 1. Architecture and workflow of the AI-enabled dual-mentor psychological support closed-loop system

2.3.1 Data collection and monitoring

Weekly reflective journals, communication texts between students and mentors, and internship behavioral data (e.g., task completion, attendance, and assessment performance) were automatically collected through the platform to establish a comprehensive multi-source database for psychological monitoring.

2.3.2 AI-based psychological monitoring and risk alert

Based on emotion analysis principles and behavioral indicators, the system continuously analyzed text data and behavioral patterns to estimate interns' psychological risk levels, which were subsequently categorized into three levels: low, moderate, or high. Risk classification was determined using the following markers: (1) Low risk: negative emotion

word frequency < 5% in reflective journals and communication texts, with no negative behavioral indicators (e.g., task non-completion, absenteeism); (2) Moderate risk: negative emotion word frequency 5%–15%, or presence of 1–2 negative behavioral indicators, or self-reported stress-related keywords (e.g., “tired,” “anxious”); (3) High risk: negative emotion word frequency > 15%, or ≥ 3 negative behavioral indicators, or detection of critical psychological markers (e.g., self-harm ideation, depression-related keywords, expressed intention to quit). These thresholds were established through natural language processing (NLP) sentiment analysis algorithms calibrated against validated psychological scales and subsequently validated through expert consensus among 5 nursing education specialists and 3 clinical psychologists.

2.3.3 Tiered response

For interns classified as low risk, routine monitoring was maintained without additional intervention.

For those classified as moderate risk, the system automatically delivered psychological support resources (e.g., relaxation audio and stress-management materials), and mentors were notified to provide follow-up support as needed.

For those classified as high risk, both school-based mentors and clinical mentors received immediate alerts and were required to conduct timely communication with the interns and, when necessary, refer them to psychological professionals.

2.3.4 Feedback and optimization

All intervention actions and follow-up outcomes were recorded on the platform to support continuous evaluation and iterative optimization of the system.

2.4 Instruments

2.4.1 Clinical skills assessment

A standardized clinical skills assessment developed by the cooperating hospitals was used. Scores ranged from 0 to 100, with scores ≥ 85 defined as excellent.

2.4.2 Emotional exhaustion

The emotional exhaustion subscale of the Maslach Burnout Inventory–General Survey (MBI-GS) was used.^[15] The subscale consists of five items rated on a 7-point Likert scale, with higher scores indicating higher levels of emotional exhaustion. Cronbach’s α coefficient in this study was 0.86. The MBI-GS is a widely used instrument with well-established reliability and validity.^[13]

Coping and anxiety-related constructs commonly assessed in nursing education research include Brief COPE and GAD-7.^[14–16] While the MBI-GS was the primary instrument for this study, the Brief COPE and GAD-7 are frequently em-

ployed in nursing education research to assess coping strategies and anxiety, respectively. The Brief COPE demonstrates acceptable internal consistency in Chinese populations (Cronbach’s $\alpha = 0.75$ for the overall scale, with subscale α ranging from 0.55 to 0.82),^[17] and the GAD-7 has shown excellent reliability (Cronbach’s $\alpha = 0.89$ –0.92) and validity for detecting generalized anxiety disorder in similar demographics.^[15] These instruments were considered during the study design phase and inform the broader context of psychological assessment in nursing internship research.

2.4.3 Internship satisfaction

A self-developed internship satisfaction questionnaire was constructed by the research team based on established theoretical frameworks of clinical learning satisfaction, following a rigorous development process. Initially, 15 items were generated through literature review and focus group interviews with 8 nursing interns and 4 clinical mentors. Content validity was established by a panel of 5 nursing education experts (Content Validity Index = 0.91). The scale was then pilot-tested with 30 nursing interns (not included in the main study), leading to the refinement of the final 9-item instrument across three dimensions: mentor support (3 items), personal growth (3 items), and environmental adaptation (3 items). Items were rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). The overall Cronbach’s α coefficient in this study was 0.89.

2.5 Data collection procedure

Baseline data were collected during the first week of internship, and posttest data were collected one week before the end of the semester. Clinical skills assessment data were collected at the end of the internship period.

2.6 Data analysis

SPSS version 26.0 was used for statistical analysis. Descriptive statistics were presented as mean \pm standard deviation or frequency and percentage. Paired *t*-tests were used for within-group comparisons. Chi-square tests were used for categorical data. Analysis of covariance (ANCOVA) was conducted to compare posttest outcomes between groups while controlling for baseline scores. Statistical significance was set at $p < .05$.

2.7 Ethical considerations

Ethical approval was obtained from the institutional ethics committee. All participants provided written informed consent prior to participation, and confidentiality and anonymity were assured.

3. RESULTS

3.1 Baseline characteristics

A total of 200 nursing interns were included in the final analysis (experimental group, n = 100; control group, n = 100). There were no significant between-group differences

in demographic characteristics (age and gender) or baseline outcome measures (emotional exhaustion and internship satisfaction) (all $p > .05$), indicating that the two groups were comparable prior to the intervention (see Table 1).

Table 1. Baseline characteristics of participants

Variables	Experimental Group (n = 100)	Control Group (n = 100)	Statistic	p-value
Age (years, mean ± SD)	20.4 ± 0.8	20.5 ± 0.9	$t = 0.82$.414
Female, n (%)	86 (86.0)	88 (88.0)	$\chi^2 = 0.19$.662
Baseline emotional exhaustion (mean ± SD)	17.02 ± 3.58	16.89 ± 3.61	$t = 0.26$.795
Baseline internship satisfaction (mean ± SD)	3.55 ± 0.60	3.57 ± 0.59	$t = -0.24$.810

Notes. Data are presented as mean ± SD or n (%). No significant differences were found between groups at baseline.

3.2 Clinical skills performance

At the end of the internship period, the proportion of interns rated as “excellent” in the clinical skills assessment was significantly higher in the experimental group than in the control group (28.0% vs. 11.0%). The between-group difference was statistically significant based on the chi-square test ($\chi^2 = 9.82, p = .002$) (see Table 2). This rate is consistent with the baseline performance observed in the control group (11.0%), reflecting the challenge of achieving high-level clinical competence under traditional supervision models without AI-enhanced support.

Table 2. Comparison of clinical skills performance between groups

Group	Total (n)	Excellent, n (%)	χ^2	p-value
Experimental group	100	28 (28.0)	9.82	.002
Control group	100	11 (11.0)		

Notes. Excellent clinical skills were defined as a score ≥ 85 on the standardized clinical skills assessment.

3.3 Within-group changes in emotional exhaustion and internship satisfaction

Paired t -tests were conducted to examine changes in emotional exhaustion and internship satisfaction from pretest to posttest within each group.

In the experimental group, posttest emotional exhaustion scores were significantly lower than pretest scores, whereas posttest internship satisfaction scores were significantly higher than pretest scores (both $p < .001$). In contrast, no statistically significant changes were observed in the control group for either emotional exhaustion or internship satisfaction (both $p > .05$) (see Table 3).

3.4 Between-group comparisons of posttest outcomes (ANCOVA)

ANCOVA was performed to compare posttest outcomes between groups while controlling for baseline (pretest) scores.

Table 3. Within-group comparisons of emotional exhaustion and internship satisfaction before and after the intervention

Group	Outcome	Pretest (mean ± SD)	Posttest (mean ± SD)	t	p-value
Experimental	Emotional exhaustion	17.02 ± 3.58	14.25 ± 3.42	6.21	< .001*
	Internship satisfaction (mean score)	3.55 ± 0.60	4.05 ± 0.51	7.08	< .001*
Control	Emotional exhaustion	16.89 ± 3.61	16.80 ± 3.65	0.41	.682
	Internship satisfaction (mean score)	3.57 ± 0.59	3.58 ± 0.62	-0.18	.857

Notes. Paired t -tests were used for within-group comparisons. ns = not significant ($p > .05$). * $p < .001$.

After adjustment for baseline levels, the experimental group demonstrated significantly lower posttest emotional exhaustion scores compared with the control group ($F = 25.34, p < .001$). In addition, the experimental group showed significantly higher overall internship satisfaction scores and significantly higher scores across all three satisfaction dimensions (mentor support, personal growth, and environmental

adaptation) than the control group (all $p < .01$) (see Table 4).

4. DISCUSSION

The present study developed and empirically evaluated an AI-enabled dual-mentor psychological support closed-loop system for nursing interns. Using a quasi-experimental design, the findings demonstrate that the intervention significantly

improved clinical skills performance, reduced emotional exhaustion, and enhanced internship satisfaction among nursing interns. These results provide empirical support for integrat-

ing artificial intelligence–assisted psychological monitoring with the dual-mentor model in clinical nursing education.

Table 4. Between-group comparisons of posttest outcomes using ANCOVA

Outcome	Experimental Group (mean ± SD)	Control Group (mean ± SD)	F	p-value
Emotional exhaustion	14.25 ± 3.42	16.80 ± 3.65	25.34	< .001
Internship satisfaction (mean score)	4.05 ± 0.51	3.58 ± 0.62	18.56	.008
Mentor support	4.12 ± 0.58	3.65 ± 0.72	16.23	.009
Personal growth	4.08 ± 0.53	3.59 ± 0.68	17.45	.008
Environmental adaptation	3.95 ± 0.61	3.50 ± 0.75	15.87	.010

Notes. ANCOVA = analysis of covariance. Baseline (pretest) scores were entered as covariates.

4.1 Effects of the system on clinical skills development

The results showed that the proportion of interns achieving excellent clinical skills performance was significantly higher in the experimental group than in the control group. This finding is consistent with previous research indicating that technology-supported learning platforms can enhance nursing students’ clinical competence and learning engagement.^[12, 18]

One possible explanation is that psychological well-being plays a foundational role in learning effectiveness. High levels of stress and emotional exhaustion may impair concentration, memory, and motivation, thereby hindering skill acquisition. By providing continuous psychological monitoring and timely support, the AI-enabled system may have alleviated interns’ emotional burden, allowing them to focus more effectively on clinical learning tasks. This interpretation aligns with Li and Shi’s^[5] findings that emotional exhaustion is negatively associated with work engagement and performance.

Moreover, the dual-mentor framework ensured that both school-based mentors and clinical mentors participated in supporting interns’ learning processes. Previous studies have shown that structured dual-mentor or mentorship models contribute to improved role adaptation and skill development in nursing students.^[6, 7] The present study extends this evidence by demonstrating that embedding AI-assisted monitoring into the dual-mentor model further strengthens its educational impact.

4.2 Effects of the system on emotional exhaustion

It is important to emphasize that the AI-enabled system functioned as a supportive tool designed to enhance, rather than replace, the established dual-mentor framework. The system increased the sensitivity and timeliness of psychological monitoring by identifying early signs of distress that might be overlooked in traditional periodic supervision, thereby

enabling mentors to provide more targeted and timely support.

Emotional exhaustion is a core dimension of burnout and is highly prevalent among nursing students and newly graduated nurses.^[3, 4] The present study found that interns in the experimental group experienced a significant reduction in emotional exhaustion after the intervention, whereas no significant change was observed in the control group.

This finding suggests that the AI-enabled closed-loop system was effective in identifying early signs of psychological distress and facilitating timely intervention. Unlike traditional approaches that rely primarily on mentors’ subjective observation, the system continuously analyzed text and behavioral data to generate risk alerts, thereby increasing the sensitivity of psychological monitoring. Similar benefits of automated or AI-assisted mental health support tools have been reported in previous studies, including the use of conversational agents and digital interventions for reducing symptoms of depression and anxiety.^[19]

Furthermore, the tiered response mechanism ensured that interventions were matched to interns’ risk levels, ranging from automated resource delivery to mentor-led communication and professional referral. Such a differentiated support strategy is consistent with recommendations from prior research emphasizing the importance of personalized psychological interventions in educational settings.^[9, 20]

4.3 Effects of the system on internship satisfaction

Internship satisfaction reflects interns’ overall perceptions of learning support, professional growth, and adaptation to the clinical environment. The present study found that interns in the experimental group reported significantly higher overall satisfaction and higher scores across all satisfaction dimensions than those in the control group.

These results indicate that the AI-enabled dual-mentor system not only addressed psychological needs but also contributed to a more supportive and responsive learning environment. Previous studies have shown that mentorship quality and perceived support are key determinants of nursing students' satisfaction and professional identity formation.^[7,8] By enhancing communication efficiency and providing timely feedback, the present system may have strengthened interns' sense of being supported and valued.

Importantly, the improvement in satisfaction may also be linked to the observed reductions in emotional exhaustion and improvements in clinical performance, suggesting a positive interaction among psychological well-being, learning experience, and educational outcomes.

4.4 Innovation and practical implications

The primary innovation of this study lies in the integration of AI-assisted psychological monitoring with an established dual-mentor model, forming a closed-loop system characterized by data collection, risk alert, tiered response, and feedback optimization. This approach moves beyond single-function applications of AI in nursing education and provides a practical, scalable model for digital transformation.

From a practical perspective, the system was implemented on an existing educational platform, which minimizes development costs and facilitates replication in other vocational colleges. The findings suggest that vocational nursing programs may consider adopting similar AI-enabled support systems to enhance both educational quality and student well-being.

The model also offers a reference for other health-related disciplines that face similar challenges in internship stress management and student support.

4.5 Limitations and future directions

Several limitations should be acknowledged. First, participants were recruited from a single vocational college and two affiliated hospitals, which may limit generalizability. Second, the intervention period covered only one semester; long-term effects remain unknown. Third, the accuracy of AI-based emotional analysis depends on algorithm optimization and data quality.

Future research should involve multi-center studies, longer follow-up periods, and further refinement of predictive algorithms. Exploring additional outcome indicators, such as professional identity and retention intention, may also provide deeper insight into the system's impact.

5. CONCLUSION

This study developed and empirically validated an AI-enabled dual-mentor psychological support closed-loop system for nursing interns. The system served as an added supportive tool that enhanced the existing dual-mentor framework by enabling early identification of psychological distress and facilitating timely, tiered interventions, without replacing the essential role of human mentorship.

The findings indicate that integrating artificial intelligence-based psychological monitoring with a structured dual-mentor framework can significantly enhance clinical skills performance, reduce emotional exhaustion, and improve internship satisfaction. Notably, the AI program was successful in identifying early signs of stress in students, thereby instituting appropriate support systems to assist students. By embedding continuous data-driven assessment, tiered response mechanisms, and coordinated mentor interventions into routine internship management, the proposed system offers a feasible, scalable, and cost-effective approach for addressing psychological challenges during clinical training. This model provides a practical and replicable pathway for integrating artificial intelligence into vocational nursing education and contributes evidence for advancing digital transformation and precision psychological support in clinical education.

ACKNOWLEDGEMENTS

We are deeply grateful to the Teaching Reform Project of Zhejiang Dongfang Polytechnic (Project No. DF2025JGYB34) for providing the essential financial support that made this research possible. We sincerely thank Wenzhou People's Hospital and the Affiliated Hospital of Zhejiang Dongfang Polytechnic for their generous support in facilitating the clinical internship placements and data collection. Our heartfelt appreciation goes to all the clinical mentors and nursing education specialists who dedicated their time and expertise to guide the interns and validate our AI-based monitoring system. We are particularly indebted to the 5 nursing education experts and 3 clinical psychologists whose consensus validation was crucial for establishing the risk classification thresholds. Finally, we extend our warmest thanks to the 200 nursing interns who participated in this study—their willingness to share their experiences and reflections formed the foundation of this research.

AUTHORS CONTRIBUTIONS

Yingying Huang, as the first and corresponding author, was responsible for study design, data collection, manuscript drafting, and overall project coordination. Xingxing Yang was responsible for data analysis, manuscript revision, and

critical review. Both authors made substantial contributions to this study and approved the final manuscript.

FUNDING

This work was supported by the Teaching Reform Project of Zhejiang Dongfang Polytechnic Project No.DF2025JGYB34.

CONFLICTS OF INTEREST DISCLOSURE

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

INFORMED CONSENT

Obtained.

ETHICS APPROVAL

The Publication Ethics Committee of the Association for Health Sciences and Education. The journal's policies adhere to the Core Practices established by the Committee on Publication Ethics (COPE).

PROVENANCE AND PEER REVIEW

Not commissioned; externally double-blind peer reviewed.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

DATA SHARING STATEMENT

No additional data are available.

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