

Academic resilience of nursing students during COVID-19: An analysis using machine learning methods

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Abstract

Aim: This cross-sectional study investigates the factors that contribute to academic resilience among nursing students during COVID-19 pandemic.

Design: A cross-sectional study.

Methods: A survey was conducted in a general hospital between November and December 2022. The Nursing Student Academic Resilience Inventory (NSARI) model was used to assess the academic resilience of 96 nursing students. The Boruta method was then used to identify the core factors influencing overall academic resilience, and rough set analysis was used to analyse the behavioural patterns associated with these factors.

Results: Attributes were categorised into three importance levels. Three statistically significant attributes were identified ("I earn my patient's trust by making suitable communication," "I receive support from my instructors," and "I try to endure academic hardship") based on comparison with shadow attributes. The rough set analysis showed nine main behavioural patterns. Random forest, support vector machines, and backpropagation artificial neural networks were used to test the performance of the model, with accuracies ranging from 73.0% to 76.9%.

Conclusion: Our results provide possible strategies for improving academic resilience and competence of nursing students.

KEYWORDS

cross-sectional study, machine learning, nursing, nursing education, resilience

Zhu Liduzi Jiesisibieke and Mao Ye contributed equally to this study.

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1 | INTRODUCTION

Resilience generally refers to the ability or skill to adapt positively to difficulties or unpleasant situations, recover from adversity, and learn from it (Hanewald, 2011; Masten, Best, & Garmezy, 1990). Academic resilience refers to the ability to recover and resume normal work activities despite stressful academic experiences (Cassidy, 2016). Individuals with high academic resilience can remain motivated and perform well in their studies even in stressful situations (Martin & Marsh, 2006). Although observational studies have expanded our understanding of academic resilience, gaps remain that need to be addressed. The concept of resilience is interpreted differently across various disciplines and populations, and the use of different measurement tools complicates comparisons between countries or regions (Tudor & Spray, 2017). Furthermore, little research has been conducted on academic resilience among nursing students during pandemics such as COVID-19.

Since the outbreak of the COVID-19 pandemic, nursing students have experienced new challenges in their studies and practice. Studying and internships are the two main aspects of these new challenges. Nursing students must adapt to online learning methods, in which insufficient education, family burden, and academic integrity are common concerns (Bdair, 2021; Cengiz et al., 2022). Despite being considered as "digital citizens," some Chinese students face challenges with online learning owing to varying financial levels (Gu, 2022). During internships, nursing students are under considerable mental pressure to control infections and often experience negative emotions because of heavy workloads; hence, their professional identity levels also decrease (Eweida et al., 2020; Luo & Mao, 2022). Academic resilience requires a combination of studying and internship processes to effectively apply or transfer knowledge to real-life work practice (Wang et al., 2021). Understanding the important features of assessing the academic resilience of nursing students will contribute to the development of learning programs and clinical practices, thereby improving public health.

Previous research has tended to relate academic resilience to student well-being (Eva et al., 2020; Grande et al., 2022). A questionnaire was designed in 2016 to measure academic resilience. However, it did not cater for nursing students (Cassidy, 2016). Nursing students should complete their courses and internships in hospitals. Therefore, in the context of pandemics such as COVID-19, academic resilience is more statistically significant. According to mixed-design evidence, optimism, communication, self-esteem/evaluation, self-awareness, trustworthiness, and self-regulation are important factors for developing academic resilience among nursing students (Ali-Abadi et al., 2021). However, these important features are yet to be fully elucidated. Machine learning can be employed to address these challenges (Bzdok & Meyer-Lindenberg, 2018; Chen et al., 2022). Based on the literature review, we hypothesised that there are some important features of academic resilience in nursing students, including characteristics of the students themselves and their environment, such as support from their surroundings, effective communication, and other related factors. We also hypothesised

that a behavioural pattern of academic adaptability would emerge among nursing students in hospitals. Therefore, this study investigates the factors that contribute to academic resilience among nursing students, as measured by the Nursing Student Academic Resilience Inventory (NSARI), particularly during the challenges posed by the COVID-19 pandemic.

2 | MATERIALS AND METHODS

2.1 | Research design

During the first stage, based on a literature review and our research purpose, we used an academic resilience assessment table (Ali-Abadi et al., 2021). To obtain the total score for assessing the academic resilience of nursing students and get a better understanding of the academic resilience status of each nursing student, we added one decision variable to the current factor table: "In general, I believe I have a good academic resilience level." (D). During the second stage, we used the Boruta method to select items critical to overall academic resilience (D). During the third stage, we used RSA to determine the rules that reflect the association between the condition and decision variables (D).

2.2 | NSARI scale

In this study, we used features developed by Ali-Abadi et al. (2021) (Table 1). The contents were mainly from a mixed-design study in which the authors constructed a feature table based on Stephen's resilience model (Stephens, 2013). A survey questionnaire was distributed to nursing students (Ali-Abadi et al., 2021; Stephens, 2013). These features include optimism (O), communication (C), self-esteem/evaluation (SE), self-awareness (SA), trustworthiness (T), and self-regulation (SR). Optimism (O) is a positive attitude toward studies and internships, and many studies have shown that optimism positively affects academic resilience (Martono et al., 2022). Communication (C) denotes the effects of communication between students and patients, instructors, and other related healthcare staff on stress. Good communication with other parties increases self-confidence (Subke et al., 2020). High self-esteem/evaluation (SE) is important for building positive interpersonal relationships and reducing stress (Chung, 2014; Lee & Kim, 2005). Self-awareness (SA) has long been accepted as crucial to increased competence and professionalism (Eckroth-Bucher, 2010). Nursing students can behave better if they obtain trustworthiness (T) from patients themselves, their family, and friends (Amsrud et al., 2019). Those who adhere to a goal and work efficiently [i.e., with self-regulation (SR)] are more motivated and have better academic resilience (Hwang & Shin, 2018). Details regarding how each item was selected have been described previously (Ali-Abadi et al., 2021). Each feature had between four and five items. In general, the factor table was well designed, with Cronbach's alpha of 0.88, intraclass correlation coefficient of 0.88 (95% CI: 0.82–0.93), accuracy index of 0.892, and Bartlett's test

TABLE 1 Nursing student academic resilience inventory (NSARI) model.

Dimension	Items
Optimism (O)	There are many opportunities in nursing field for me. (O ₁) I am looking forward to be a great nurse in near future. (O ₂) I am looking forward to an economic prosperity in the field of nursing. (O ₃) I have a positive attitude toward nursing. (O ₄) I am motivated to participate in internships. (O ₅)
Communication (C)	Patient companion reduces my stress. (C ₁) Understanding my terms by my instructor, reduces my stress. (C ₂) Cooperation by nurses reduces my stress. (C ₃) Having a good communication with attending physicians reduces my stress. (C ₄)
Self-esteem/evaluation (SE)	My instructors trust my judgement in taking care of the patients. (SE ₁) I get support from my instructors. (SE ₂) I have sufficient confidence in taking care of patients. (SE ₃) I have adequate knowledge in (science of) nursing. (SE ₄)
Self-awareness (SA)	I manage the difficulties of my academic years. (SA ₁) I'm not disappointed by the failures during my education. (SA ₂) I have adequate motivation to participate in theory sessions. (SA ₃)
Trustworthiness (T)	I earn my patient's trust by making a suitable communication. (T ₁) By strengthening my nursing knowledge, I will do my best to take care of the patient. (T ₂) I get support from my family. (T ₃) My friends and colleagues support me. (T ₄)
Self-regulation (SR)	I examine all options to reach my goals. (SR ₁) My attempts are to strive and reach my goals. (SR ₂) I learn better by executing bedside procedures. (SR ₃) I try to endure the academic hardship. (SR ₄)
In general, I believe I have a good academic resilience level (D)	

Note: Values for all items are strongly disagree (1), disagree (2), uncertain (3), agree (4), and strongly agree (5).

being significant ($p < 0.001$), and it has good construct validity (Ali-Abadi et al., 2021).

2.3 | The Boruta method

The Boruta method is a feature selection technique that aims to identify the most relevant conditional attributes related to a study subject while eliminating irrelevant ones. Specifically, it selects the conditional attributes that are most important in determining the overall academic resilience. This approach differs from traditional feature selection methods, as it seeks to uncover all mechanisms underlying the study subject rather than just selecting the smallest set of features that best fits a particular model. Unlike general feature screening approaches, the Boruta method focuses on identifying a set of conditional attributes that are most relevant to the dependent variable or decision attribute rather than merely reducing the feature dimensionality (Zhou et al., 2023). The Boruta method's primary process has been previously documented (Kursa & Rudnicki, 2010). The method involves shuffled real features to construct shadow features, and then merges real and shadow features to generate a feature matrix for training. Finally, the feature importance points based

on the shadow features were set as reference values to select the feature set related to the subject of interest.

The key aspects of the Boruta method include the following. First, the condition variables are interdependent. Second, after excluding one condition variable, if the precision of the decision variable decreases, a certain condition variable is not necessarily unimportant (Kursa & Rudnicki, 2010; Wiesław & Maksymilian, 2020). The Boruta method was developed using the core concept of random forest (RF), with randomness added to mitigate the influence of random fluctuations and correlations. This improved feature selection method can assist researchers in accurately identifying significant features (Kursa & Rudnicki, 2010), which are crucial for disease prediction (Zhou et al., 2023) and exploring disease prognosis (Maurya et al., 2023) in clinical settings. Boruta analysis was conducted using the "Boruta" package (version 8.0.0) in R.

2.4 | The RSA method

RSA is a data mining method used for data classification (Pawlak, 1982). The method determines the upper and lower sets to obtain an approximate boundary area for the target (Berridge, 1981).

Therefore, RSA has been used to identify behavioural rules and predict behaviours (Amin et al., 2017). RSA methods are considered effective at addressing imprecise, inconsistent, and incomplete data (Sai et al., 2006), and they unambiguously classify lower approximation or positive regions as belonging to the target set, whereas the upper approximation is considered to contain sets that are possibly members of the target set (Pawlak & Skowron, 2007). In healthcare settings, RSA is often used for risk feature identification (Cheng et al., 2021), health service quality assessment (Du et al., 2021), and disease diagnosis models (Jiang et al., 2017). The decision-making rules generated by the RAS method are straightforward and easy to comprehend, enabling decision-makers to understand the underlying behaviour patterns and develop targeted interventions or improvement programs. While the RAS method has been successfully applied in medicine, to our knowledge, it has not yet been explored for academic resilience. In this study, the RSA method was conducted using the “RoughSets” package (version 1.3-7) in R.

2.5 | Research Ethics Committee approval

This study was approved by the Ethics Committee of the REDACTED Hospital (approval number: 2023L-01-04). The survey link provided mandatory consent to participate in the formal questionnaire. However, no personal information was collected to safeguard the privacy and confidentiality of the interns. The participants' privacy and confidentiality were protected throughout the study. All procedures were performed in accordance with the relevant guidelines and regulations stipulated in the Declaration of Helsinki.

2.6 | Data collection and participants

Survey data were obtained from a tertiary general hospital in REDACTED, China. The survey was conducted from November to December 2022 in the context of routine COVID-19 epidemic prevention and control. This study used convenience sampling, and 96 valid questionnaires were collected. Before participants completed the questionnaire, the staff members explained the research purpose and procedures to the nursing students. They also emphasised that the information was anonymous and that they could withdraw their participation at any time.

3 | RESULTS

3.1 | Participants characteristics

Of the participants that were included, 92.7% were female, most of whom were in the age range of 17–24 years, 19.8% were undergraduates, and 80.2% were junior college students. The statistical results for the participants are presented in Table 2.

TABLE 2 The background description.

Items	n (%)
Gender	
Male	7 (7.3%)
Female	89 (92.7%)
Age (years old)	
≤20	30 (31.2%)
21–23	64 (66.7%)
≥24	2 (2.1%)
Internship (weeks)	
≤30	59 (61.4%)
31–39	28 (29.2%)
≥40	9 (9.4%)
Education	
Junior college student	77 (80.2)
Undergraduate student	19 (19.8)

3.2 | Estimating the importance of influencing academic resilience

Tables 3 and 4 present the estimated importance of each item/attribute obtained using the Boruta method. The former is the result of the first model, and all attributes are divided into three categories: confirmed, rejected, and tentative.

Confirmed indicates that the item/attribute is important for determining overall academic resilience and should be retained, whereas rejection means that the item/attribute should be excluded. Furthermore, items/attributes in the tentative category are difficult to identify; that is, it is difficult to confirm whether they should be retained or excluded.

Among the results of this modelling, “SE3,” “C4,” “C5,” “SA3,” “O4,” “SA1,” “C3,” “SR1,” “SR2,” “SE4,” “SR3,” “O3,” “T3,” “C1,” “O1,” “C2,” and “T4” were “Confirmed.” “SA2,” “T2,” “O2,” and “SE1” were “Rejected.” “T1,” “SE2,” and “SR4” were qualified as “Tentative.” Next, the method continuously compared and analysed the median attribute score with the median score of the most important shadow attribute. Finally, “T1,” “SE2,” and “SR4” were confirmed as important. The results of the entire process are shown in Figure 1.

3.3 | Analysing behaviour patterns affecting academic resilience

The study data were modelled stochastically five times using the RSA method. This resulted in 117 behavioural patterns/decision rules, of which nine main rules that had an impact on the academic resilience of nursing students were screened out (Table 5). In rule one, for example, if a nursing student agrees strongly with “I have sufficient confidence in taking care of patients” (SE_3), “My attempt to strive and reach my goals” (SR_2), and “I am motivated to participate in internships” (O_5), then they strongly agree that they have good academic resilience and adaptability.

TABLE 3 Results of preliminary estimation and screening.

	meanImp	medianImp	minImp	maxImp	normHits	Decision
O1	4.294	4.317	1.706	6.631	0.839	Confirmed
O2	2.198	2.167	-1.078	4.331	0.116	Rejected
O3	4.507	4.557	2.748	6.011	0.874	Confirmed
O4	7.824	7.842	5.971	9.568	0.985	Confirmed
O5	8.514	8.533	6.724	10.019	0.990	Confirmed
C1	4.371	4.344	2.090	5.998	0.834	Confirmed
C2	3.741	3.777	1.506	5.345	0.769	Confirmed
C3	6.465	6.473	4.416	9.008	0.975	Confirmed
C4	8.758	8.764	6.906	10.278	1.000	Confirmed
SE1	1.373	1.628	-0.107	2.216	0.005	Rejected
SE2	2.905	2.936	0.787	5.113	0.523	Tentative
SE3	9.621	9.658	7.424	11.969	1.000	Confirmed
SE4	5.747	5.687	2.070	8.530	0.975	Confirmed
SA1	7.438	7.349	5.850	9.510	0.990	Confirmed
SA2	2.382	2.453	-0.651	4.758	0.221	Rejected
SA3	7.876	7.906	5.839	9.306	0.995	Confirmed
T1	3.055	3.118	0.686	4.829	0.588	Tentative
T2	2.370	2.375	0.489	3.891	0.121	Rejected
T3	4.351	4.404	2.266	5.833	0.864	Confirmed
T4	3.398	3.365	1.608	4.831	0.683	Confirmed
SR1	6.362	6.448	4.151	7.807	0.980	Confirmed
SR2	5.947	5.979	4.521	7.679	0.970	Confirmed
SR3	4.856	4.911	3.195	6.542	0.899	Confirmed
SR4	2.961	2.907	0.439	5.526	0.538	Tentative

3.4 | Results of five random validations

This study's survey data confirmed the accuracy of the model using common data mining methods, including RF, support vector machine (SVM), and backpropagation artificial neural network (BPANN), as listed in Table 6.

Table 6 lists the accuracy rates of each method that was randomly executed five times. The average accuracy rates of each method are as follows: 75.3% for RSA, 76.9% for RF, 73.7% for SVM, and 73.0% for BPANN. From the perspective of average accuracy, the rankings from high to low were as follows: RF, RSA, SVM, and BPANN.

4 | DISCUSSION

4.1 | Critical factors affecting the academic resilience of nursing students

Among the important rules, four conditional attributes require particular attention: "I have sufficient confidence in taking care of patients." (SE_3) (five times), "I manage the difficulties of my academic years." (SA_1) (five times), "I am motivated to participate in internships." (O_5) (four times); and "Having a good communication with attending physicians reduces my stress." (C_4) (four times).

Confidence is an essential attribute for nursing students to possess when caring for patients because it can enhance patient safety and prevent mistakes (Alharbi & Alharbi, 2022). Nurses constantly develop and improve their confidence from their student years to their professional careers (Makarem et al., 2019). However, because nursing students are still in the early stages of their clinical practice, stress and low confidence can arise from the discrepancy between theoretical education and clinical practice, and from a lack of practical skills and uncertain workplace conditions. Coupled with the impact of the pandemic, the difficulties nursing students face during their academic years are more intense than ever. Online teaching replaced the traditional face-to-face teaching method, and students experienced difficulties stemming from concerns about their academics, health, families, finances, and clinical practice being put on hold (Dewart et al., 2020; Kochuvilayil et al., 2021). Motivation is the basis of learning, particularly in this unique context. Although nursing students face physical and mental difficulties and challenges, they must be motivated to succeed in the new learning environment when interning (Russo et al., 2023). Therefore, support from school faculty and hospital staff should be provided for nursing students to adapt more rapidly to major health crises (Uğur et al., 2022). As future nurses, nursing students will work in interprofessional teams, and communication is a necessary skill. Mastering good communication skills can help solve clinical problems more efficiently, achieve good cooperation with physicians, and improve perceptions of collaboration

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TABLE 4 Results of the final estimation and screening.

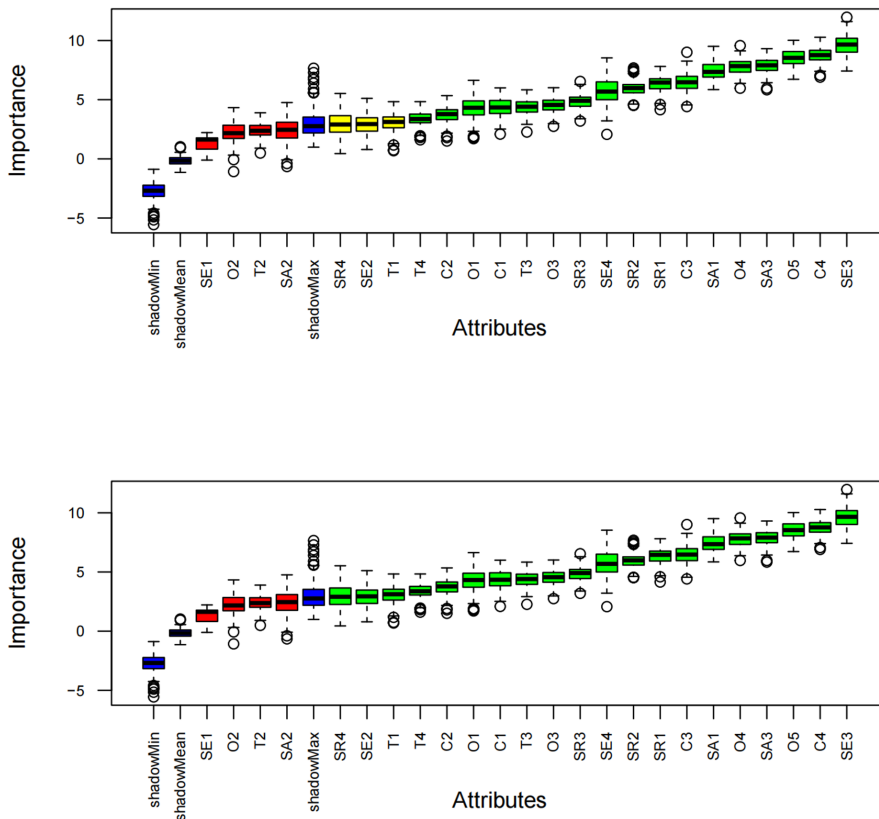


FIGURE 1 The importance of each item/conditional attribute.

TABLE 5 Most important decision rules in five-time random modelling.

No.	Condition (IF)	Decision (then)	Support size	Laplace
1	IF [SE ₃ is 5] and [SR ₂ is 5] and [O ₅ is 5]	5	18	0.9048
2	IF [C ₄ is 5] and [SE ₃ is 5]	5	18	0.9048
3	IF [SA ₁ is 5] and [O ₅ is 5]	5	17	0.9
4	IF [C ₄ is 5] and [SE ₃ is 5]	5	15	0.8889
5	IF [C ₄ is 5] and [SA ₁ is 5] and [SA ₃ is 5]	5	15	0.8889
6	IF [SE ₃ is 5] and [SA ₁ is 5] and [O ₄ is 5]	5	12	0.8667
7	IF [SA ₁ is 5] and [O ₅ is 5] and [SR ₂ is 5]	5	17	0.9
8	IF [T ₁ is 5] and [C ₄ is 5] and [O ₅ is 5] and [SA ₁ is 5]	5	14	0.8824
9	IF [O ₄ is 5] and [O ₃ is 5] and [SE ₃ is 5]	5	16	0.8947

Note: 1=strongly disagree, 2=disagree, 3=uncertain, 4=agree, 5=strongly agree. Support size: Number of samples supporting this rule. Laplace: The larger the number, the higher the laplace.

Among the nine most important rules, the conditional attribute plays a key role in indicating the conditions, situations, and behaviours under which the corresponding results (i.e., decisions) are produced. Based on these rules, nine conditional attributes were identified: SE₃ (five times), SA₁ (five times), O₅ (four times), C₄ (four times), SR₂ (two times), O₄ (two times), SA₃ (once), T₁ (once), and O₃ (once).

TABLE 6 Accuracy rate (%) of each method randomly executed five times.

	RSA	RF	SVM	BPANN
1	72.2%	77.1%	79.0%	65.0%
2	72.7%	76.0%	68.4%	70.0%
3	89.5%	77.1%	84.2%	70.0%
4	73.3%	77.1%	68.4%	75.0%
5	68.8%	77.1%	68.4%	85.0%
Average	75.3%	76.9%	73.7%	73.0%

and confidence in handling difficulties (Liaw et al., 2020). Moreover, studies have shown that human patient simulation schemes (Fuglsang et al., 2022), realistic simulation scenarios (Teixeira et al., 2022), and service-learning experiences (Mumba et al., 2022) can help nursing students become more confident and motivated and improve their communication skills to manage internship difficulties.

4.2 | Practical application of behaviour patterns/ rules of academic resilience for nursing students

This practical application combines the behavioural patterns of academic resilience of nursing students with hospital clinical experience and proposes several measures and schemes. In this study, nine main

rules were identified from the data. Four of the rules had a support size greater than 17 and were numbered 1, 2, 3 and 7. Hospital decision-makers and nursing managers should pay close attention to these rules.

If [SE₃ is 5], [SR₂ is 5], and [O₅ is 5], then [D=5].

Nursing students strongly agree that having sufficient confidence in patient care, striving to reach their goals, and motivating themselves to participate in internships reflect good academic resilience and adaptability. Nursing students with low confidence often have inadequate clinical experience, and as internships progress and hospital training is conducted, they may become more confident (Aboshaiqah et al., 2018). Therefore, nursing educators and managers should develop realistic clinical learning goals for nursing students, establish phased training and practice tasks, and periodically monitor their completion. Increasing nursing students' knowledge and clinical practice experiences through intentional and planned systematic training increases their confidence in patient care. To motivate nursing students during the clinical practice process, clinical nursing educators should encourage and affirm them. Additionally, tailored training and support can improve students' adherence to regulations and protocols, ultimately preparing them for the demands of the nursing profession (Abuzaid, Elshami, & Tekin, 2022).

If [C₄ is 5] and [SE₃ is 5], then [D=5].

If a nursing student strongly perceives good communication with attending physicians and sufficient confidence in patient care, then they strongly believe that they have good academic resilience and adaptability. Nursing students must master communication skills with nurses, physicians, other students, and patients. Therefore, nursing managers should focus on promoting communication abilities among nursing students. Studies have shown that blended learning (mixing face-to-face and online methods) and learning through artificial intelligence (AI)-enabled virtual reality simulations can significantly improve professional communication skills (Liaw et al., 2023; Valentina et al., 2019). Nursing students will learn more and become more confident in their ability to care for patients as their communication skills improve.

If [SA₁ is 5] and [O₅ is 5], then [D=5].

This rule refers to a nursing student who thinks they can manage the difficulties of their academic years, is motivated to participate in internships, and has good academic resilience and adaptability. Nursing students who can overcome academic difficulties are often perceived as having greater adaptability and problem-solving abilities and are perceived to be more resilient than their peers. Therefore, to cultivate nursing students' resilience, nursing managers should foster problem-solving skills, encourage them to face challenges, and promote proactive action. For example, AI and other new teaching-assisted tools can be used to improve efficiency. However, nursing students currently have a poor understanding of AI (Abuzaid et al., 2023; Abuzaid, Elshami, & Fadden, 2022). In the future, incorporating AI into their studies can address this gap.

If [SA₁ is 5], [O₅ is 5], and [SR₂ is 5], then [D=5].

Compared with the previous rule, this rule includes an additional item: "My attempts are to strive and reach my goals." (SR₂). The

determination to work hard to achieve goals is a driving force for nursing students and a manifestation of their dedication. Nursing managers and educators should help nursing students set achievable goals and provide positive feedback when they achieve them.

4.3 | Advantages of the hybrid machine learning model

This study's decision-making model has the following three advantages: (1) Based on the existing NSARI scale, the Boruta method was used to further screen out the important factors affecting academic resilience from the behavioural patterns of nursing students in the case hospitals. This method closely resembles the behaviour of the respondents. (2) Based on these important factors, the rough set method was used to analyse the behavioural patterns affecting academic resilience, and decision rules were adopted as the expression mode. Furthermore, it provides a good explanatory method for the behavioural patterns behind the data. This method makes it easy for hospital nursing managers to understand behavioural patterns. These two points arise from the advantages of this research model, which can be combined with nursing practice management experience to provide personalised promotional management strategies and programs that more closely resemble the respondents. Furthermore, (3) from the perspective of method combination, the Boruta method is based on the viewpoint that condition attributes affect decision attributes to filter important attributes. In other words, there is a mutual influence between the attributes. Furthermore, the behavioural law behind the data was analysed using the RSA method. These two methods are based on the mutual influence of attributes and factors and the complementary comprehensive effect of decision analysis. The former is used to screen for important attributes, whereas the latter is used to parse behavioural patterns.

4.4 | Practical implications

Our research offers insights into the concept of academic resilience, specifically in the context of nursing students. Academic resilience is crucial for individuals to overcome obstacles and attain their academic objectives. This is particularly important for nurses, who need to demonstrate persistence and adaptability to consistently provide high-quality healthcare services in all challenging situations, not just during a pandemic. Nursing students need to develop a strong sense of academic resilience to overcome the challenges they face during their education and internships. To achieve this, it is essential to identify the key factors that influence academic resilience. By doing so, stakeholders can create targeted support strategies or programs, such as peer support, to foster academic and professional growth among nursing students and foster a sense of community as they adapt to the evolving education landscape (Edwards et al., 2022). Beyond the COVID-19 pandemic, our findings have implications for informing

and enhancing education and learning processes in response to future emergent public health events.

4.5 | Research limitations

To the best of our knowledge, few studies were conducted to analyse the academic resilience of a group of nursing students based on the NSARI scale and to use the Boruta and RSA dual machine learning methods. Although there are some advantages to this research, there are some limitations. First, the results should not be inferred for nursing students in other hospitals because they are restricted to case study subjects. Second, the demographic breakdown indicates a predominant participation of women and junior college students. It would be beneficial to address the implications of this demographic skew on the generalizability of the findings. Future studies should use a more diverse or representative sample to improve the study's external validity. Third, while the features selected based on Stephen's resilience model are comprehensive, other factors should be considered in the future when assessing the academic resilience of nursing students. Fourth, to further enhance validation and reliability, comparison with other scales measuring similar constructs could provide insight into the relative strengths and potential limitations of the NSARI scale. Therefore, in the future, we could replicate this study using reliable scales and compare the findings. Fifth, because our study population was selected on a voluntary basis, volunteer bias is possible. Sixth, we should also take note that our sample size was relatively smaller than previous studies. However, one study on academic resilience had a comparable sample size (Ríos-Risquez et al., 2016). The relatively small sample size could potentially bias our results. Finally, although the Boruta method of feature selection is innovative, the possible interdependency of the condition variables may influence the results.

5 | CONCLUSIONS

By identifying the key attributes of nursing students' academic resilience, our findings provide possible strategies for improving their academic resilience and competence. By learning to adapt to a changing environment and academic challenges, nursing students can acquire the necessary skills and mindsets to become more professional in their careers. Furthermore, by improving their academic resilience, nursing students can fulfil their key roles in the healthcare field and provide better patient care.

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CONFLICT OF INTEREST STATEMENT

The authors have no proprietary interest in any aspect of this study.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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