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Canonical correlation analysis on the association between learning environment and self-directed learning ability among nursing undergraduates

| Journal: | BMJ Open |
| --- | --- |
| Manuscript ID | bmjopen-2021-058224 |
| Article Type: | Original research |
| Date Submitted by the Author: | 13-Oct-2021 |
| Complete List of Authors: | Tang, Li-qing; Wannan Medical College Zhu, Li-jun; Wannan Medical College Wen, Li-ying; Wannan Medical College Wang, An-shi; Wannan Medical College Jin, Yue-long; Wannan Medical College Chang, Wei-wei; Wannan Medical College |
| Keywords: | PUBLIC HEALTH, Epidemiology < ONCOLOGY, MEDICAL EDUCATION & TRAINING |
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Canonical correlation analysis on the association between learning environment and self-directed learning ability among nursing undergraduates

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ABSTRACT

Objectives The aim of this study was to explore the relationship between perception of the learning environment and self-directed learning (SDL) ability among nursing undergraduates.

Design, setting and participants A cross-sectional study was conducted in December 2020. The participants of this study were junior and senior undergraduate nursing students from Wannan Medical College in Anhui Province, China. A total of 1,096 students aged 16-22 years.

Outcome measures The Chinese version of the Dundee ready educational environment measure (DREEM) questionnaire and a validated Chinese version of college students' SDL ability scale were used to assess the perceptions of students about their learning environment and their SDL ability. Canonical correlation analysis was performed to evaluate their correlation.

Results The total score of learning environment was 120.60 (the scoring rate: 60.30%) and the score of SDL ability was 89.25 (the scoring rate: 63.75%). Canonical correlation analysis showed that the first canonical correlation coefficient was 0.701 and the contribution rate was 94.26%. The perception of learning environment mainly determined by students’ perception of learning (SPL) and students’ academic self-perceptions (SASP), and SDL ability mainly determined by self-management ability and cooperative learning ability. SPL and SASP have positively correlated...
with self-management ability and cooperative learning ability. Multiple linear regression analysis showed that SPL, SASP, SPA, and SSSP have a significant impact on SDL ability.

**Conclusions** The SDL ability of nursing undergraduates was not high. SPL and SASP have positively correlated with self-management ability and cooperative learning ability.

**Key words** Perception; Learning environment; Self-directed learning; Nursing; Students

**Strengths and limitations of this study**

1. This is the first study to explore the correlation between learning environment and SDL ability.

2. Canonical correlation analysis was performed to examine the relationship between learning environment and SDL ability.

3. This study is a cross-sectional study and cannot draw the conclusion of causality.

4. All information was obtained from self-reported questionnaires, which may lead to recall bias and reporting bias.
INTRODUCTION

Self-directed learning (SDL) refers to the initiative to judge learning needs, establish learning goals, select and implement appropriate learning strategies, and evaluate learning outcome with or without help from others.\(^1\) SDL ability is a kind of comprehensive ability that students show in the process of learning.\(^2\) Nursing is an applied discipline that requires students to have high-strength skills and nursing is a work closely related to the people's life safety and health interests.\(^3\) Clinical nursing is a profession that requires rapid knowledge update and lifelong learning.\(^4\) Nursing staff need to continuously learn new knowledge and new technologies. Relying only on the knowledge learned during school is far from meeting clinical needs and this requires nursing staff to strengthen their SDL ability to adapt to the rapid update of nursing knowledge. In order to adapt to the ever-changing social health care needs, cultivating senior nursing talents who can independently acquire knowledge has become the main goal and task of training talents for higher nursing education.\(^5\) Good SDL ability is the foundation of lifelong learning for nursing undergraduates.\(^6\) The studies in China showed that the awareness of SDL ability among nursing undergraduates was weak, and many nurses also regarded learning as a burden outside of work.\(^7\)\(^9\) The formation of SDL ability does not happen overnight, so it is particularly important to cultivate SDL ability during college.\(^10\)

The education environment is everything that happens inside a medical university, including the learning environment, perception of infrastructure, interaction between students and classmates, teachers’ attitudes and skills, and many related factors.\(^11\) Students’ perception of educational environment play a subtle role in learning and contributes positively to learning input, students’ achievement, which can stimulate students’ interest in learning, and can also dissipate their learning
The study reported by Zafar et al. found that the depression of medical students was related to the negative perception of the learning environment. For a long time, the creation of the learning environment of universities and the development of students’ SDL ability have been independent in China. The rationality of the means to create an learning environment is often valued, while the ability of students to learn independently is often ignored, which leads to disharmony between the two. How to use an advanced and effective educational methods to create a harmonious and adaptable learning environment, so that nursing students can master medical knowledge and clinical skills proficiently, and at the same time have a good sense of SDL, has become an urgent solution for universities.

Understanding students’ perception of the learning environment also helps improve the quality of learning. The purpose of this study was to investigate the correlations between learning environment and SDL ability among nursing undergraduates. First, to understand the students’ perceptions of learning environment and the levels of SDL ability. Second, because the learning environment and SDL ability are multidimensional, it is difficult to directly evaluate the relationship between them. Canonical correlation analysis is a multivariate statistical method which has been widely used to study the associations between two sets of variables. Therefore, through canonical correlation analysis, this study analyzes the correlation between learning environment and SDL ability. This is of great significance for exploring the educational reform plan to improve the SDL ability of nursing undergraduates.

METHODS

Study designs and participants
This study was a cross-sectional descriptive survey conducted in December 2020. The participants of this study were junior and senior undergraduate nursing students from Wannan Medical College in Anhui Province, China. Undergraduate nursing education lasts 3 years and is divided into 2 years each of basic sciences and clinical medicine education and 1 year of internship. The school’s nursing program has three grades, each grade has 20 classes, and each class has 25-33 students. Students in grades 3 are internships in the hospital, no questionnaire survey was conducted on them. All students in grades 1-2 (1150 students) participated in the field survey. Informed consent was obtained and anonymity was ensured from all the participants. Finally, 1,096 respondents were included in the final analysis (response rate: 1,096/1,150=95.30%).

Ethical approval for this study was granted by the Ethics Committee of Wannan Medical College(LL-2020BH2086).

Instruments

The self-designed questionnaire included three parts: sociodemographic characteristics, learning environment, and SDL ability.

Demographic characteristics

Demographic variables include gender (male, female), age, grade (first grade, second grade), and birthplace (countryside, town).

Chinese version of the Dundee ready educational environment measure (DREEM)

The Chinese version of the DREEM survey, translated by the medical education research center of China Medical University, was used to assess students’ perception of their learning environment. This scale contains 50 items, of which nine are reverse-scored. Each item was scored on a five-point Likert scale from 0 (strongly disagree) to 4 (strongly agree). The DREEM inventory has 5 sub-scales: students’

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perceptions of learning (SPL) (12 items), students' perceptions of teachers (SPT) (11 items), students' academic self-perceptions (SASP) (8 items), students' perceptions of atmosphere (SPA) (12 items), and students' social self-perceptions (SSSP) (7 items). The total DREEM score was calculated by adding the sum score of five sub-scales (total score range: 0-200). The scale has good validity and the Cronbach α coefficient of each dimension is between 0.60-0.84. Calculation of average scoring rate (%): the actual score of the sub-scale is divided by the full score of the sub-scale. The higher the score rate, the better the learning environment.

**Self-directed learning (SDL) Ability**

SDL ability was measured by a validated Chinese version of College Students’ Self-directed Learning Ability Scale. This scale contained 28 items, of which five are reverse-scored and each item was rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scale included three dimensions: (1) self-management ability, 10 items including the ability to determine learning needs, time management ability and learning monitoring ability (e.g., “I often set learning goals”); (2) information capability, 11 items including information acquisition ability and information analysis and processing ability (e.g., “It is difficult for me to grasp the key points in my study”); and (3) cooperative learning ability, 7 items including the ability to communicate and ask for help (e.g., “When other student ask me for my learning experience, I can always say one or two points”). The total score of SDL ability was the sum of the score for each item (total score range: 0-140). A higher score indicated a higher ability of SDL. In present study, the questionnaire had good reliability and validity, and Cronbach’s α for self-management ability, information capability, and cooperative learning ability subscale was 0.802, 0.709, and 0.764, respectively.
Data Analysis

The statistical analysis was performed by SPSS 25 for Windows. Scores for total and each domain were expressed as mean ± standard deviation (SD). Categorical variables (e.g. gender, grade etc.) were expressed as frequencies or percentage. Independent samples t-test were used to compare the means between different groups. Pearson’s correlation coefficients were calculated to examine the correlation between the learning environment and SDL ability. Canonical correlation analysis was used to analyze the correlation between learning environment and SDL ability. Each dimension of learning environment are taken as X group variables, the corresponding typical variable is U. Each dimension of SDL ability are taken as group Y variables and the corresponding typical variable as V. A multiple linear regression analysis was used to analyze learning environment on SDL ability among nursing undergraduates. A value of $P < 0.05$ (two-tailed) was considered statistically significant.

RESULTS

Characteristics Description

Among the 1,096 nursing students in this study, 462 students were freshmen and 634 students were sophomores. The overall mean age was 19.34 ± 1.09 years (range: 16-22 years). In terms of gender, females accounted for 79.65% of the total respondents, and males 20.35%. Only 46.35% of students would plan to pursue their major in the future. Other basic information of 1,096 students was listed in Table 1.

The overall DREEM mean score was 120.60 (60.30%) of a maximum score of 200, indicating a relative overall satisfaction with the environment but with room for improvement (Table 2). According to sub-scale, the mean score was 29.01 ± 6.46 for SPL (60.43%), 28.63 ± 6.27 for SPT (65.07%), 17.81 ± 4.54 for SASP (55.66%),
28.92 ± 6.42 for SPA (60.25%), and 16.25 ± 3.80 for SSSP (58.04%) items. The average scoring rate of SASP is relatively lower in all dimensions, followed by SSSP (Table 2).

The overall SDL ability mean score was 89.25 (63.75%) of a maximum score of 140. According to sub-scale, the mean score was 32.81±5.56 for self-management ability (65.62%), 34.71±4.47 for information capability (63.11%), and 21.73 ± 3.65 for cooperative learning ability (62.09%) (Table 3).

Correlations between the learning environment and SDL ability

Spearman’s Correlation

The total DREEM scores were positively related with the total score of SDL ability ($r=0.680, P<0.001$). Similarly, all sub-scale scores of DREEM were positively related with three dimensions of SDL ability ($P<0.001$, Table 4). In particular, the correlations between learning environment and SDL ability scores were above 0.4 in all subscales, indicating there was a moderate level of correlation.

Canonical Correlation

For the canonical correlation analysis, the X variables represented DREEM (X1 = SPL, X2 = SPT, X3 = SASP, X4 = SPA, X5 = SSSP) and the Y variables represented SDL ability (Y1 = Self-management ability, Y2 = Information capability, and Y3 = Cooperative learning ability). Three pairs of typical variables were extracted from the results of canonical correlation analysis, and the correlation coefficients of the first two pairs (0.701 and 0.221, respectively) were statistically significant ($P < 0.05$, Figure1). The cumulative contribution rate of the first typical variables has reached 94.26%. Therefore, this study took the first typical variable for explanation.

In canonical correlation analysis, the absolute value of standardization coefficient represents the weight. The standardized linear functions of the first pair of
typical variables are listed as follows: $U_1(DREEM) = -0.377X_1 + 0.094X_2 - 0.350X_3 - 0.212X_4 - 0.240X_5$; $V_1(SDL\ ability) = -0.470Y_1 - 0.299Y_2 - 0.357Y_3$.

$U_1$ mainly determined by $X_1$ (students’ perception of learning) and $X_3$ (students’ academic self-perceptions), and $V_1$ mainly determined by $Y_1$ (self-management ability) and $Y_3$ (cooperative learning ability). Further typical structural analysis showed that $X_1$ and $X_3$ were negatively correlated with $U_1$, $Y_1$ and $Y_3$ were negatively correlated with $V_1$. So, students’ perception of learning(SPL) and students’ academic self-perceptions(SASP) have positively correlated with self-management ability and cooperative learning ability.
Multiple linear regression analysis of educational environment on SDL ability among nursing students

In multiple linear regression analysis, the total score of SDL ability was defined as the dependent variable and scores on 5 dimensions of educational environment were defined as independent variables. After adjust gender, age, class, birthplace, and professional choice, the analysis showed positive significant relationships between score of SDL ability and SPL score ($\beta=0.263$, $P<0.001$); SASP score ($\beta=0.245$, $P<0.001$); SPA score ($\beta=0.153$, $P=0.002$) (Table 7).

DISCUSSION

The score rates of self-management ability (65.62%), information capability (63.11%), and cooperative learning ability (62.09%) were all above 60%, indicating that the SDL ability of nursing undergraduates was at the middle level. Among them, the highest score was self-management ability, which was consistent with the study reported by Xu et al. in 2019.\cite{21} This might be related to the fact that nursing undergraduates were mainly females, and they had better self-planning and self-management for learning. The research showed the females had clear learning goals, strong learning motivation, and learning monitoring ability.\cite{22}

The total score of learning environment was 120.60, with a scoring rate of 60.30%, which indicated “a more positive than negative” perception of the environment among nursing undergraduates. Students are generally satisfied with the learning environment. Similar to this study, the results of two studies conducted in China and India, with scores of 121.95/200 and 119/200, respectively.\cite{23,24} Nursing undergraduates have the highest rate of SPT and the lowest rate of SASP, similar findings was seen in studies conducted by Gong et al. in 2018.\cite{25} This might be related to the teaching reform of schools attended by the subjects, including the great
adjustment of teaching content and teaching methods in recent years. In terms of
teaching courses, the case teaching and video teaching in our school provide students
with more opportunities to communicate with teachers. However, SASP had the
lowest mean score percentage, followed by SSSP for all participants. This might be
explained by the fact the students have been passive receptive learning and rely on
mechanical memory to cope with the exam. So that the academic nature of learning
has not been developed.\textsuperscript{26} Although the scores for all subscales showed positive
perceptions among nursing students, there is a need for improvement in all five
domains of the learning environment, specifically in SASP subscale. It is suggested
that for the cultivation of SDL ability of nursing students, the focus of improving the
learning environment should be on the academic perception domain.

Environment is a huge stimulus, which provides a strong driving force for
educational objects. Sayed et al. indicated that a collaborative, academy, and
supportive environment may increase the participation of nursing students, while an
environment of competition, pressure or threats may reduce the motivation of students
to learn and weaken their interest in the learning process.\textsuperscript{27} This is the first study to
explore the correlation between learning environment and SDL ability. The results of
linear correlation analysis showed that subscales of learning environment were
positively correlated with subscales of SDL ability among nursing students, indicating
that students with higher score of learning environment have a better SDL ability.
Further canonical correlation analysis showed that learning environment mainly
determined by SPL and SASP, and SDL ability mainly determined by
self-management ability and cooperative learning ability. SPL and SPA have
positively correlated with self-management ability and cooperative learning ability,
suggesting that nursing students with better perception of learning and academic have
the stronger self-management ability and cooperative learning. The above results
indicates that changing some aspects of the learning environment can significantly
improve the learning enthusiasm and initiative of nursing undergraduates.
Students with high satisfaction with the learning environment have a high sense of happiness, which can improve students’ learning passion. Teachers can improve students’ perception of learning environment by changing traditional teaching methods, so as to improve their SDL ability. Alshawish et al. found that case-based blended teaching can improve students’ perception of learning environment. In order to actively participate in classroom teaching and master the knowledge points of learning, students consciously do a good job of pre class preview and post class review, which can improve the self-management ability of students. Zu et al. changed the nursing education environment through case teaching method and fully mobilized students’ interest in autonomous learning. Students actively participated in learning, and their subjective initiative was mobilized to the greatest extent.

When nursing undergraduates who have high thirst for knowledge and actively participate in classroom teaching encounter difficulties in the learning process, they will acquire this knowledge through communication and exchange with classmates and teachers, reflecting their good learning and cooperation ability. A quasi-experimental study concluded that the training program based on maker education improved students' creativity, learning interest, and cooperative learning ability. The learning environment directly affected students’ learning methods and academic achievements, and students’ satisfaction with the learning environment could in turn encourage students to learn happily. Therefore, to improve the SDL ability of nursing students, it is indispensable to create an adaptive learning environment. The state of “teacher-centered in the teaching process” should be changed, and nursing students should be placed at the center of education. Teachers should adopt exploratory and innovative teaching methods to change the learning role of nursing students based on “listening, memorizing, and memorizing”, and maximize the enthusiasm and initiative of nursing students in learning, which can improve their SDL ability.
LIMITATIONS

Some limitations should be taken into account when interpreting these findings in this paper. Firstly, this study is a cross-sectional study and can not draw the conclusion of causality. Secondly, all information was obtained from self-reported questionnaires, which may lead to recall bias and reporting bias. In addition, the nursing undergraduates in this study come from one medical college, and the results should be extrapolated carefully.

CONCLUSION

In summary, the learning environment of nursing students is at the middle level, and SDL ability is not high. SPL and SASP have positively correlated with self-management ability and cooperative learning ability. Nursing education management departments and nursing educators should learn advanced teaching experience at home and abroad, stimulate nursing students’ learning enthusiasm to the greatest extent and improve nursing students’ SDL ability by changing the learning and academic education environment.

Abbreviations

DREEM: Dundee Ready Educational Environment Measure; SPL: Students' Perceptions of Learning; SPT: Students' Perceptions of Teachers; SASP: Students' Academic Self-Perceptions; SPA: Students' Perceptions of Atmosphere; SSSP: Students' Social Self-Perceptions; SD: Standard Deviation; ANOVA: Analysis of variance

Acknowledgments The authors thank all the participating students for their willingness to complete the questionnaires. The authors would also like to thank the editors of this manuscript.
**Contributors** TLQ and CWW : Writing-original draft, preparation, Investigation. CWW, JYL and ZLJ : Writing-review & editing. WAS and WLY: Conceptualization, Methodology, Supervision. All authors read and approved the final manuscript.

**Funding** This study was supported by the key projects of Anhui Province Quality Engineering (2020jyxm2086; 2015zjhh017); Wannan Medical College Quality Project (2020jyxm18).

**Competing interests** None declared.

**Patient and Public Involvement** No patient involved

**Patient consent for publication** Not applicable.

**Ethics approval** This study was approved by the Ethics Committee of Wannan Medical College(LL-2020BH2086). Written informed consent forms were obtained from the subjects that participated in this study.

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| Variables         | Category     | Frequency | Percentage (%) |
|-------------------|--------------|-----------|----------------|
| Gender            | Male         | 223       | 20.35          |
|                   | Female       | 873       | 79.65          |
| Class             | Freshman     | 462       | 42.15          |
|                   | Sophomore    | 634.00    | 57.85          |
| Age               | Mean ± SD: 19.34 ± 1.09, Range (16–22) |           |                |
| Birthplace        | Countryside  | 802       | 73.18          |
|                   | Town         | 294       | 26.82          |
| Do you plan to pursue this major in the future? | Yes | 508 | 46.35 |
|                   | No           | 141       | 12.86          |
|                   | Uncertain    | 447       | 40.79          |
Table 2  Mean (SD) subscale and total DREEM scores for nursing undergraduates

| DREEM Domains | Full marks | Mean (SD)       | Average scoring rate(%) |
|---------------|------------|-----------------|-------------------------|
| SPL           | 48         | 29.01(6.46)     | 60.43                   |
| SPT           | 44         | 28.63(6.27)     | 65.07                   |
|   | SASP   | SPA    | SSSP   | Total DREEM score |
|---|--------|--------|--------|------------------|
|   | 32     | 48     | 28     | 200              |
|   | 17.81(4.54) | 28.92(6.42) | 16.25(3.80) | 120.60(24.72) |
|   | 55.66  | 60.25  | 58.04  | 60.30            |

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching;
SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions
Table 3  Mean (SD) subscale and total score of SDL ability for nursing undergraduates

| Latitude                  | Full marks | Mean (SD)    | Average scoring rate (%) |
|---------------------------|------------|--------------|--------------------------|
| Self-management ability   | 50         | 32.81 (5.56) | 65.62                    |
| Information capability    | 55         | 34.71 (4.47) | 63.11                    |
| Cooperative learning ability | 35       | 21.73 (3.65) | 62.09                    |
| Total score               | 140        | 89.25 (12.12)| 63.75                    |
Table 4 Spearman’s correlation coefficients between learning environment and SDL ability among nursing undergraduates

| Latitude | Self-management ability | Information capability | Cooperative learning ability | Total score |
|----------|-------------------------|------------------------|-----------------------------|-------------|
| SPL      | 0.608**                 | 0.549**                | 0.555**                     | 0.648**     |
| SPT      | 0.532**                 | 0.427**                | 0.411**                     | 0.525**     |
| SASP     | 0.565**                 | 0.529**                | 0.585**                     | 0.630**     |
| SPA      | 0.590**                 | 0.546**                | 0.546**                     | 0.636**     |
| SSSP     | 0.574**                 | 0.520**                | 0.565**                     | 0.625**     |
| Total DREEM score | 0.639**             | 0.570**                | 0.585**                     | 0.680**     |

**There was a significant correlation at 0.01 level (bilateral)**
Table 5 Outcomes of canonical correlation analysis and likelihood ratio test

| Correlation | Proportion(%) | Cumulative | F   | P     |
|-------------|---------------|------------|-----|-------|
| 1           | 0.701         | 94.26      | 61.110 | <0.001 |
| 2           | 0.221         | 4.96       | 7.976 | <0.001 |
| 3           | 0.087         | 0.78       | 2.754 | 0.041  |
Table 6 Standardized coefficients of the first and second pairs of typical variables

| SDL ability | Variables                | typical variable 1 | typical variable 2 |
|-------------|--------------------------|--------------------|--------------------|
| DREEM (X)   | SPL (X1)                 | -0.377             | -0.122             |
|             | SPT (X2)                 | 0.094              | 1.467              |
|             | SASP (X3)                | -0.350             | -0.491             |
|             | SPA (X4)                 | -0.212             | -0.160             |
|             | SSSP (X5)                | -0.240             | -0.443             |
| SDL ability (Y) | Self-management ability (Y1) | -0.470             | 1.287             |
|             | Information capability (Y2) | -0.299             | -0.004             |
|             | Cooperative learning ability (Y3) | -0.357             | -1.309             |
Table 7 Multiple linear regression analysis of educational environment on SDL ability among nursing students

| Independent variables | B   | SE  | β   | t    | P*  |
|-----------------------|-----|-----|-----|------|-----|
| Constant              | 48.820 | 2.659 | 18.360 | <0.001 |
| SPL                   | 0.493 | 0.095 | 0.263 | 5.208 | <0.001 |
| SPT                   | -0.140 | 0.079 | -0.073 | -1.780 | 0.075 |
| SASP                  | 0.654 | 0.098 | 0.245 | 6.695 | <0.001 |
| SPA                   | 0.289 | 0.092 | 0.153 | 3.141 | 0.002 |
| SSSP                  | 0.535 | 0.126 | 0.168 | 4.253 | <0.001 |

*The adjustment factors: gender, age, class, birthplace, and planning to pursue this major in the future.

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching;
SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; B: unstandardized coefficient; SE: standard error; β: standardized coefficient.
Figure 1 Structure coefficient of canonical factors among nursing undergraduates

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; SDL: Self-directed learning
The association of learning environment and self-directed learning ability among nursing undergraduates-a cross-sectional study using canonical correlation analysis

| Journal: | BMJ Open |
|----------|----------|
| Manuscript ID | bmjopen-2021-058224.R1 |
| Article Type: | Original research |
| Date Submitted by the Author: | 05-May-2022 |
| Complete List of Authors: | Tang, Li-qing; Wannan Medical College Zhu, Li-jun; Wannan Medical College Wen, Li-ying; Wannan Medical College Wang, An-shi; Wannan Medical College Jin, Yue-long; Wannan Medical College Chang, Wei-wei; Wannan Medical College, |
| Primary Subject Heading: | Medical education and training |
| Secondary Subject Heading: | Medical education and training, Medical management, Nursing, Public health |
| Keywords: | PUBLIC HEALTH, Epidemiology < ONCOLOGY, MEDICAL EDUCATION & TRAINING |
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The association of learning environment and self-directed learning ability among nursing undergraduates—a cross-sectional study using canonical correlation analysis

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ABSTRACT

Objectives: This study explores the relationship between perception of the learning environment and self-directed learning (SDL) ability among nursing undergraduates.

Design, setting, and participants: A cross-sectional study was conducted in December 2020. The participants were 1,096 junior and senior undergraduate nursing students (aged 16-22) from Wannan Medical College in Anhui Province, China.

Outcome measures: The Chinese version of the Dundee Ready Educational Environment Measure (DREEM) questionnaire and a validated Chinese version of college students’ SDL ability scale were used to assess students’ perceptions about their learning environment and their SDL ability. Canonical correlation analysis was performed to evaluate their correlation.

Results: The total score of learning environment was 120.60 (scoring rate: 60.30%) and the score of SDL ability was 89.25 (scoring rate: 63.75%). Analysis indicated that the first canonical correlation coefficient was 0.701 and the contribution rate was 94.26%. The perception of learning environment was mainly determined by students’ perception of learning (SPL) and academic self-perceptions (SASP), and SDL ability mainly determined by self-management ability and cooperative learning ability. SPL and SASP are positively correlated with self-management ability and cooperative learning ability. Multiple linear regression analysis revealed that SPL, SASP, SPA, and SSSP have a significant impact on SDL ability.

Conclusions: The SDL ability of nursing undergraduates was not high. SPL and SASP are positively correlated with self-management ability and cooperative learning ability. Nursing educators can improve students’ SDL ability by changing their learning environment, such as new student-centered teaching methods.

Key words Perception; Learning environment; Self-directed learning; Nursing; Students

Strengths and limitations of this study

1. This is the first study to explore the correlation between learning environment and SDL ability among nursing undergraduates in China.

2. An advanced statistical method (Canonical Correlation Analysis) was used to evaluate the reportedly unexplored relationship between the multiple dimensions of learning environment and self-directed learning.

3. A cross-sectional study approach was adopted and causality cannot be clearly proven.

4. The nursing undergraduates come from one medical college in western Anhui Province in China and the nationwide generalizability was limited.
INTRODUCTION

Self-directed learning (SDL) refers to the initiative to judge learning needs, establish learning goals, select and implement appropriate learning strategies, and evaluate learning outcome with or without help from others.\(^1\) SDL ability is a form of comprehensive ability that students exhibit in the process of learning.\(^2\) Nursing is an applied discipline that requires students to have high-strength skills and is closely related to life safety and health interests.\(^3\) Clinical nursing is a profession that requires rapid knowledge update and lifelong learning.\(^4\) Nursing staff need to continuously learn new knowledge and new technologies. Relying only on the knowledge learned during school does not meet clinical needs and nursing staff are required to strengthen their SDL ability to adapt to the rapid update of nursing knowledge. To adapt to the ever-changing social health care needs, cultivating senior nursing talents who can independently acquire knowledge has become the main goal and task of training talents for higher nursing education.\(^5\) Good SDL ability is the foundation of lifelong learning for nursing undergraduates.\(^6\) Research in China revealed that the awareness of SDL ability among nursing undergraduates was weak, and many nurses also regarded learning as a burden outside of work.\(^7-9\) The formation of SDL ability does not happen overnight, so it is particularly important to cultivate SDL ability during college.\(^10\)

The education environment is everything that happens inside a medical university, including the learning environment, perception of infrastructure, interaction between students and classmates, teachers’ attitudes and skills, and many related factors.\(^11\) Students’ perception of the educational environment plays a subtle role in learning and contributes positively to learning input, students’ achievement, which can stimulate students’ interest in learning, and can also impact their motivation.\(^12-14\) Understanding students’ perception of the learning environment also helps improve the quality of learning.\(^15\) Dundee Ready Education Environment Measure (DREEM) is an educational tool based on questionnaire survey, which can be used to “quantify” the educational environment.\(^16\) It was translated into a variety of
languages and has been used worldwide\textsuperscript{17-19}. An educational experiment in an Iranian medical sciences university revealed DREEM helps reduce students’ cognitive deficiencies in many aspects of the educational environment and helps identify problems in improvement\textsuperscript{20}.

A survey of nursing and emergency medical services majors at King Saud University\textsuperscript{21} shows that a supportive learning environment, including good teaching, clear goals and standards, appropriate assessment, appropriate workload and emphasis on independence, encourages students to participate in the SDL process, so as to improve their academic performance. Padugupati et al.\textsuperscript{22} found the flipped classroom learning environment was a dynamic and more social space, which could effectively improve students’ learning behavior, including deep learning, self-efficacy, SDL, and so on. A mixed approach study involving Indian medical students highlighted that given the importance of SDL in medicine, curriculum design should increase learning activities to promote SDL and provide strategies to change the learning environment conducive to SDL\textsuperscript{23}. At present, the formed educational environment in Chinese colleges and universities is not conducive to the cultivation and development of students’ SDL ability\textsuperscript{24}. How to use advanced and effective educational methods to create a harmonious and adaptable learning environment, so that nursing students can master medical knowledge and clinical skills proficiently, and at the same time have a good sense of SDL, has become an urgent issue for universities.

This study investigated the correlations between learning environment and SDL ability among nursing undergraduates. The first purpose of this study is to understand students’ perceptions of the learning environment and the levels of SDL ability. The learning environment and SDL ability are multidimensional, it is difficult to directly evaluate the relationship between them. While, canonical correlation analysis is a multivariate statistical method that has been widely used to study the associations between two sets of variables.\textsuperscript{25} Therefore, the second purpose of this study is to evaluate the relationship between learning environment and SDL ability by using canonical correlation analysis. This is of great significance for exploring the
METHODS

Study designs and participants

This study was a cross-sectional descriptive survey conducted in December 2020. The participants were junior and senior undergraduate nursing students from Wannan Medical College in Anhui Province, China. Undergraduate nursing education lasts three years and is divided into two years basic sciences and clinical medicine education and one year of internship. The school’s nursing program has three grades, each grade has 20 classes, and each class has 25-33 students. As students in grade 3 are interns, no questionnaire survey was conducted on them. All students in grades 1-2 (1150 students) participated in the field survey.

The trained investigators distributed questionnaires to students in class. After the investigators read out the unified guidance and told the students to fill in the precautions, the students completed the questionnaire anonymously in the classroom, and the investigators took back the questionnaire on site. Informed consent was obtained and anonymity was ensured from all the participants. Finally, 1,096 respondents were included in the final analysis (response rate: 1,096/1,150=95.30% ). Ethical approval for this study was granted by the Ethics Committee of Wannan Medical College (LL-2020BH2086).

Instruments

The self-designed questionnaire included three parts: sociodemographic characteristics, learning environment, and SDL ability.

Demographic characteristics

Demographic variables include gender (male, female), age, grade (first grade, second grade), and birthplace (countryside, town).

Chinese version of the Dundee Ready Educational Environment Measure (DREEM)

The Chinese version of the DREEM survey, translated by the medical education
research center of China Medical University, was used to assess students’ perception of their learning environment. This scale contains 50 items, of which nine are reverse-scored. Each item was scored on a five-point Likert scale from 0 (strongly disagree) to 4 (strongly agree). The DREEM inventory has 5 sub-scales: students’ perceptions of learning (SPL) (12 items) (e.g., “I am encouraged to participate in class”, “Long-term learning is emphasized over short-term learning”), students’ perceptions of teachers (SPT) (11 items)(e.g., “The teachers are knowledgeable”, “The teachers give clear examples”), students’ academic self-perceptions (SASP) (8 items) (e.g., “ Much of what I have to learn seems relevant to a career in health care”, “My problem-solving skills are being well developed”), students’ perceptions of atmosphere (SPA) (12 items)(e.g., “The atmosphere is relaxed during consultation teaching”, “The atmosphere motivates me as a learner”), and students’ social self-perceptions (SSSP) (7 items)(e.g.,“I have good friends in this school”, “I seldom feel lonely ”). The total DREEM score was calculated by adding the sum score of five sub-scales (total score range: 0-200). Calculation of average scoring rate (%): the actual score of the sub-scale is divided by the full score of the sub-scale. The higher the score rate, the better the learning environment. The DREEM has good validity and has been widely used among college students in China. Cronbach’s alpha values of SPL, SPT, SASP, SPA, and SSSP was 0.818, 0.864, 0.786, 0.834, and 0.675 in this study, respectively.

**Self-directed learning (SDL) Ability**

SDL ability was measured by a validated Chinese version of college students’ Self-directed Learning Ability Scale. This scale contained 28 items, of which five are reverse-scored and each item was rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scale included three dimensions: (1) self-management ability, 10 items including the ability to determine learning needs, time management ability and learning monitoring ability (e.g., “I often set learning goals”); (2) information capability, 11 items including information acquisition ability and information analysis and processing ability (e.g., “It is difficult for me to grasp
the key points in my study”); and (3) cooperative learning ability, 7 items including
the ability to communicate and ask for help (e.g., “When other student ask me for my
learning experience, I can always say one or two points”). The total score of SDL
ability was the sum of the score for each item (total score range: 0-140). A higher
score indicated a higher ability of SDL. Calculation of average scoring rate (%): the
actual score of the sub-scale is divided by the full score of the sub-scale. In present
study, Cronbach’s α for self-management ability, information capability, and
cooperative learning ability subscale was 0.802, 0.709, and 0.764, respectively.

Patient and public involvement
No patient involved in this study.

Data Analysis
The statistical analysis was performed by SPSS 25 for Windows. Scores for total and
each domain were expressed as mean ± standard deviation (SD). Categorical variables
(e.g. gender, grade etc.) were expressed as frequencies or percentage. Pearson’s
correlation coefficients were calculated to examine the correlation between the
learning environment and SDL ability. Canonical correlation analysis was used to
analyze the correlation between learning environment and SDL ability. Each
dimension of learning environment are taken as X group variables, the corresponding
typical variable is U. Each dimension of SDL ability are taken as group Y variables
and the corresponding typical variable as V. A multiple linear regression analysis was
used to analyze learning environment on SDL ability among nursing undergraduates.
A value of $P < 0.05$ (two-tailed) was considered statistically significant.

RESULTS
Characteristics Description
Among the 1,096 nursing students in this study, 462 were freshmen and 634
were sophomores. The overall mean age was $19.34 ± 1.09$ years (range: 16-22 years).
In terms of gender, females accounted for 79.65% of the total respondents, and males
20.35%. Only 46.35% of students would plan to pursue their major in the future.
Other basic information of 1,096 students was listed in Table 1. The overall DREEM mean score was 120.60 (60.30%) of a maximum score of 200, indicating a relative overall satisfaction with the environment but with room for improvement (Table 2). According to sub-scale, the mean score was 29.01 ± 6.46 for SPL (60.43%), 28.63 ± 6.27 for SPT (65.07%), 17.81 ± 4.54 for SASP (55.66%), 28.92 ± 6.42 for SPA (60.25%), and 16.25 ± 3.80 for SSSP (58.04%) domains. The average scoring rate of SASP (55.66%) is relative lower in all dimensions, followed by SSSP (58.04%) (Table 2).

The overall SDL ability mean score was 89.25 (63.75%) of a maximum score of 140. According to sub-scale, the mean score was 32.81±5.56 for self-management ability (65.62%), 34.71±4.47 for information capability (63.11%), and 21.73 ± 3.65 for cooperative learning ability (62.09%) (Table 3).

Correlations between the learning environment and SDL ability

Pearson’s Correlation

The total DREEM scores were positively related with the total score of SDL ability ($r=0.680$, $P<0.001$). Similarly, all sub-scale scores of DREEM were positively related with three dimensions of SDL ability ($P<0.001$, Table 4). In particular, the correlations between learning environment and SDL ability scores were above 0.4 in all sub-scales, indicating there was a moderate level of correlation.

Canonical Correlation

For the canonical correlation analysis, the X variables represented DREEM (X1 = SPL, X2 = SPT, X3 = SASP, X4 = SPA, X5 = SSSP) and the Y variables represented SDL ability (Y1 = Self-management ability, Y2 = Information capability, and Y3 = Cooperative learning ability). Three pairs of typical variables were extracted from the results of canonical correlation analysis, and the correlation coefficients of the first two pairs (0.701 and 0.221, respectively) were statistically significant ($P < 0.05$, Figure1) (Table 5). The cumulative contribution rate of the first typical variables has reached 94.26% (Table 5). Therefore, this study took the first typical variable for explanation.
In canonical correlation analysis, the absolute value of standardization coefficient represents the weight. The standardized linear functions of the first pair of typical variables are listed as follows: $U_1$ (DREEM) = $-0.377X_1 + 0.094X_2 - 0.350X_3 - 0.212X_4 - 0.240X_5$; $V_1$ (SDL ability) = $-0.470Y_1 - 0.299Y_2 - 0.357Y_3$ (Table 6).

$U_1$ mainly determined by $X_1$ (students’ perception of learning) and $X_3$ (students’ academic self-perceptions), and $V_1$ mainly determined by $Y_1$ (self-management ability) and $Y_3$ (cooperative learning ability). Further typical structural analysis showed that $X_1$ and $X_3$ were negatively correlated with $U_1$, $Y_1$ and $Y_3$ were negatively correlated with $V_1$. So, students’ perception of learning (SPL) and students’ academic self-perceptions (SASP) have positively correlated with self-management ability and cooperative learning ability.

**Multiple linear regression analysis of educational environment on SDL ability among nursing students**

In multiple linear regression analysis, the total score of SDL ability was defined as the dependent variable and scores on 5 dimensions of educational environment were defined as independent variables. After adjust gender, age, class, birthplace, and professional choice, the analysis showed positive significant relationships between score of SDL ability and SPL score ($\beta=0.263, P<0.001$); SASP score ($\beta=0.245, P<0.001$); SPA score ($\beta=0.153, P=0.002$) (Table 7).

**DISCUSSION**

The score rates of self-management ability (65.62%), information capability (63.11%), and cooperative learning ability (62.09%) were all above 60%, indicating that the SDL ability of nursing undergraduates was not high. Among them, the highest score rate was self-management ability, which was consistent with the results in Xu et al. (2019). This may be related to the fact that nursing undergraduates were mainly females, and they had better self-planning and self-management for learning. Female’s management learning goals are significantly more positive than males, because they use more learning self-regulation strategies and display a more positive learning attitude. And another research indicated the females had clear learning
goals, strong learning motivation, and learning monitoring ability. The total score of learning environment was 120.60, with a scoring rate of 60.30%, indicating “a more positive than negative” perception of the environment among nursing undergraduates. Students are generally satisfied with the learning environment. Similarly, the results of two studies conducted in China and India, revealed scores of 121.95/200 and 119/200, respectively. Nursing undergraduates have the highest rate of SPT and the lowest rate of SASP, and Gong et al. (2018) derived similar findings. This may be related to the teaching reform of schools attended by the subjects, including the significant adjustment of teaching content and teaching methods in recent years. In terms of teaching courses, the case teaching and video teaching in our school provide students with more opportunities to communicate with teachers. However, SASP had the lowest score rate, followed by SSSP for all participants. This may be explained by the fact the students have been passive receptive learning and rely on mechanical memory, an inefficient learning technique of rote memorization, to cope with the exam. As a result, the academic nature of learning has not been developed. In addition, self-generation of knowledge can activate deeper cognitive processing and improve long-term retention compared to the passive reception of information. It can allow students to not only acquire content knowledge, but also an understanding of inquiry skills. Some new teaching models focus on cultivating students’ SDL and in-depth learning rather than rote learning, which is conducive to improving the quality of teaching and promoting the development of education. Sahu et al. find that the SSSP correlates significantly with subjective happiness and suggest that institutions promote not only students’ academic development but also their happiness by fostering an appropriate educational environment. Although the scores for all subscales indicated positive perceptions among nursing students, there is a need for improvement in all five domains of the learning environment, specifically in SASP subscale. The possible reason is the individual’s perception and misperception of their academic ability. If people are accurate at judging their own abilities, then self-perception would have an
important role in the acquisition of education and skills. For the cultivation of nursing students’ SDL ability, the focus of improving the learning environment should be on the academic perception domain.

Environment is a major stimulus, which provides a strong driving force for educational objects. Sayed et al. indicated that a collaborative, academic, and supportive environment may increase the participation of nursing students, while an environment of competition, pressure, or threats may reduce the motivation to learn and weaken their interest in the learning process.\(^{44}\) To the best of our knowledge, this is the first study to explore the correlation between learning environment and SDL ability among nursing undergraduates. The results of linear correlation analysis revealed that subscales of learning environment were positively correlated with those of SDL ability among nursing students, indicating that students with higher scores for learning environment have a better SDL ability. Studies revealed that an SDL environment will produce a learner who is self-directed that can be a contributing factor to enhance the individual’s quality of life or in learning.\(^ {45}\) Further canonical correlation analysis indicated that learning environment was mainly determined by SPL and SASP, and SDL ability was mainly determined by self-management ability and cooperative learning ability. A survey of 4257 college students in research universities demonstrates that effective instructor facilitation can influence both students’ self-assessment of learning and perceived utility of the learning activities, and can improve SPL by improving teachers’ teaching ability.\(^ {46}\) Some studies have highlighted that psychological distress and low peer social support work together to reduce medical student SASP.\(^ {47}\) Further, a multiwave longitudinal study of Chinese children determined that contributions between SASP and achievement occurred in a progressive cascading manner.\(^ {48}\) Therefore, it is suggested that steps be taken to cultivate positive psychological states and students’ sense of achievement to improve SASP. SPL and SPA are positively correlated with self-management ability and cooperative learning ability, suggesting that nursing students with better perception of learning and academia have the stronger self-management ability and cooperative
The above results indicate that changing some aspects of the learning environment can significantly improve the learning enthusiasm and initiative of nursing undergraduates.

Students with high satisfaction with the learning environment have a high sense of happiness, which can improve students’ passion for learning. Teachers can improve students’ perception of the learning environment by changing traditional teaching methods, so as to improve their SDL ability. Alshawish et al. found that case-based blended teaching can improve students’ perception of the learning environment. Liu et al. revealed that the teaching model combining virtual simulation technology and network teaching can effectively cultivate the “student-centered” autonomous learning ability and promote the development of nursing students’ autonomous inquiry learning behavior. To actively participate in classroom teaching and master the knowledge points of learning, students consciously engage in pre-class and post-class review, which can improve their self-management ability. Zu et al. changed the nursing education environment through a case teaching method and fully mobilized students’ interest in autonomous learning. Therefore, teachers should constantly explore new education and teaching methods (such as flipped classroom, seminar and problem-based learning) to stimulate nursing students’ learning enthusiasm and promote them to adopt in-depth learning methods, so as to achieve the purpose of ability training.

When nursing undergraduates who have high thirst for knowledge and actively participate in classroom teaching encounter difficulties in the learning process, they will acquire knowledge through communication and exchange with classmates and teachers, reflecting their good learning and cooperation abilities. A quasi-experimental study concluded that the training program based on maker education improved students’ creativity, learning interest, and cooperative learning ability. The learning environment directly affected students’ learning methods and academic achievements, and satisfaction with the learning environment could in turn encourage students to adopt a more positive approach to learning. Therefore, to
improve the SDL ability of nursing students, it is indispensable to create an adaptive
learning environment. First, the instructional process is personalized in terms of
different instructional parameters such as sequence of tasks and task difficulty, time
and type of feedback, pace of learning speed, reinforcement plan, and so on. Second,
the school can provide more social and the communication opportunity for the nursing
undergraduate student in education and teaching. The teachers guide the nursing
undergraduates to use the new social platform to strengthen the unity and build a good
interpersonal relationship and communication environment. Third, the state of
“teacher-centered in the teaching process” should be changed, and nursing students
should be placed at the center of education. Hong et al. revealed that the application
of the combination model of Small Private Online Course and Objective Structured
Clinical Examination in pediatric nursing training teaching was conducive to
stimulate students’ learning interest and improve students’ professional
comprehensive ability, including interpersonal communication ability. So, teachers
should adopt exploratory and innovative teaching methods to change the learning role
of nursing students based on “listening and memorizing”, and maximize the
enthusiasm and initiative of nursing students in learning, which can improve their
SDL ability.

LIMITATIONS
When interpreting the findings of this study, some limitations should be taken into
account. First, a cross-sectional study approach was adopted and causality cannot be
clearly proven. Second, all information was obtained from self-reported questionnaires,
which may lead to recall and reporting bias. Third, the nursing undergraduates come
from one medical college in western Anhui Province and the nationwide
generalizability was still limited. A muti-institutional design from more areas is
highly prioritized in the follow-up research. Finally, this study adopted a single
quantitative data survey method. Qualitative data derived from focus groups could
help explore how nursing students approach self-directed learning, what they value in
the learning environment, and why self-perception of academic performance scores
were low. A mixed-method study (qualitative interview and quantitative survey) is highly prioritized in the follow-up research.

CONCLUSION

In summary, SDL ability of nursing undergraduates was not high. SPL and SASP are positively correlated with self-management ability and cooperative learning ability. Nursing educators can improve students’ SDL ability by changing their learning environment, such as new student-centered teaching methods. A multi-institutional and mixed-method design from more areas is highly prioritized in the follow-up research.

Abbreviations

DREEM: Dundee Ready Educational Environment Measure; SPL: Students’ Perceptions of Learning; SPT: Students’ Perceptions of Teachers; SASP: Students’ Academic Self-Perceptions; SPA: Students' Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; SD: Standard Deviation; SDL: Self-directed learning

Acknowledgments The authors thank all the participating students for their willingness to complete the questionnaires. The authors would also like to thank the editors of this manuscript.

Contributors TLQ and CWW: Writing-original draft, preparation, Investigation. CWW, JYL, WLY and ZLJ: Writing-review & editing. WAS and WLY: Conceptualization, Methodology, Supervision. All authors read and approved the final manuscript.

Funding This study was supported by the key projects of Anhui Province Quality Engineering (2020jyxm2086; 2015zjjh017); Wannan Medical College Quality Project (2020jyxm18).

Competing interests None declared.

Patient and public involvement No patient involved in this study.
Patient consent for publication  Not applicable.

Ethics approval  This study was approved by the Ethics Committee of Wannan Medical College(LL-2020BH2086). Written informed consent forms were obtained from the subjects that participated in this study.

Data availability statement  Data can be obtained from the corresponding author upon reasonable request.

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Huang HM, Cheng SF. Application of Flipped Classroom Teaching Strategy in Nursing Education. Hu Li Za Zhi 2018;65(6):5-12. Chinese
Table 1  Demographic characteristics of the participants (n=1,096)

| Variables                | Category  | Frequency | Percentage (%) |
|--------------------------|-----------|-----------|----------------|
| Gender                   | Male      | 223       | 20.35          |
|                          | Female    | 873       | 79.65          |
| Class                    | Freshman  | 462       | 42.15          |
|                          | Sophomore | 634.00    | 57.85          |
| Age                      | Mean ± SD: 19.34 ± 1.09, Range (16–22) |           |                |
| Birthplace               | Countryside | 802      | 73.18          |
|                          | Town      | 294       | 26.82          |
| Do you plan to pursue this major in the future? | Yes | 508 | 46.35 |
|                          | No        | 141       | 12.86          |
|                          | Uncertain | 447       | 40.79          |
Table 2  Mean (SD) subscale and total DREEM scores for nursing undergraduates

| DREEM Domains | Full marks | Mean (SD)   | Average scoring rate(%) |
|----------------|------------|-------------|-------------------------|
| SPL            | 48         | 29.01(6.46) | 60.43                   |
| SPT            | 44         | 28.63(6.27) | 65.07                   |
| SASP           | 32         | 17.81(4.54) | 55.66                   |
| SPA            | 48         | 28.92(6.42) | 60.25                   |
| SSSP           | 28         | 16.25(3.80) | 58.04                   |
| Total DREEM score | 200       | 120.60(24.72) | 60.30                   |

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions
### Table 3  Mean (SD) subscale and total score of SDL ability for nursing undergraduates

| Sub-scales            | Full marks | Mean (SD)     | Average scoring rate (%) |
|-----------------------|------------|---------------|--------------------------|
| Self-management ability | 50         | 32.81 (5.56)  | 65.62                    |
| Information capability | 55         | 34.71 (4.47)  | 63.11                    |
| Cooperative learning ability | 35         | 21.73 (3.65)  | 62.09                    |
| **Total score**       | **140**    | **89.25 (12.12)** | **63.75**               |
Table 4 Pearson’s correlation coefficients between learning environment and SDL ability among nursing undergraduates

| Sub-scales | Self-management ability | Information capability | Cooperative learning ability | Total score |
|------------|-------------------------|------------------------|-----------------------------|-------------|
| SPL        | 0.608**                 | 0.549**                | 0.555**                     | 0.648**     |
| SPT        | 0.532**                 | 0.427**                | 0.411**                     | 0.525**     |
| SASP       | 0.565**                 | 0.529**                | 0.585**                     | 0.630**     |
| SPA        | 0.590**                 | 0.546**                | 0.546**                     | 0.636**     |
| SSSP       | 0.574**                 | 0.520**                | 0.565**                     | 0.625**     |
| Total DREEM score | 0.639** | 0.570** | 0.585** | 0.680** |

**There was a significant correlation at 0.01 level (bilateral)**
Table 5 Outcomes of canonical correlation analysis and likehood ratio test

| Correlation | Proportion(%) | Cumulative | $F$      | $P$     |
|-------------|---------------|------------|----------|---------|
| 1           | 0.701         | 94.26      | 94.26    | 61.110  | <0.001  |
| 2           | 0.221         | 4.96       | 99.22    | 7.976   | <0.001  |
| 3           | 0.087         | 0.78       | 100.00   | 2.754   | 0.041   |
Table 6 Standardized coefficients of the first and second pairs of typical variables

| SDL ability     | Variables        | typical variable 1 | typical variable 2 |
|-----------------|------------------|--------------------|--------------------|
| DREEM (X)       | SPL (X1)         | -0.377             | -0.122             |
|                 | SPT (X2)         | 0.094              | 1.467              |
|                 | SASP (X3)        | -0.350             | -0.491             |
|                 | SPA (X4)         | -0.212             | -0.160             |
|                 | SSSP (X5)        | -0.240             | -0.443             |
| SDL ability (Y) | Self-management ability (Y1) | -0.470             | 1.287              |
|                 | Information capability (Y2) | -0.299             | -0.004             |
|                 | Cooperative learning ability (Y3) | -0.357             | -1.309             |
Table 7 Multiple linear regression analysis of educational environment on SDL ability among nursing students

| Independent variables | B     | SE  | β    | t    | P*   |
|-----------------------|-------|-----|------|------|------|
| Constant              | 48.820| 2.659| 18.360| <0.001|
| SPL                   | 0.493 | 0.095| 0.263| 5.208| <0.001|
| SPT                   | -0.140| 0.079| -0.073| -1.780| 0.075|
| SASP                  | 0.654 | 0.098| 0.245| 6.695| <0.001|
| SPA                   | 0.289 | 0.092| 0.153| 3.141| 0.002|
| SSSP                  | 0.535 | 0.126| 0.168| 4.253| <0.001|

*The adjustment factors: gender, age, class, birthplace, and planning to pursue this major in the future.

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; B: unstandardized coefficient; SE: standard error; β: standardized coefficient.
**Figure legend/caption**

**Figure 1 Structure coefficient of canonical factors among nursing undergraduates**

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; SDL: Self-directed learning
STROBE Statement—Checklist of items that should be included in reports of cross-sectional studies

| Item No | Recommendation | Page/line numbers |
|---------|----------------|-------------------|
| Title and abstract | 1 (a) Indicate the study’s design with a commonly used term in the title or the abstract | Lines 1-3, Page 1 |
| | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | Page 2 |
| **Introduction** | | |
| Background/rationale | 2 Explain the scientific background and rationale for the investigation being reported | Pages 3-4 |
| Objectives | 3 State specific objectives, including any prespecified hypotheses | Lines 112-117, Page 4 |
| **Methods** | | |
| Study design | 4 Present key elements of study design early in the paper | Line 124, Page 5 |
| Setting | 5 Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Line 124, Page 5 |
| Participants | 6 (a) Give the eligibility criteria, and the sources and methods of selection of participants | Lines 124-131, Page 5 |
| Variables | 7 Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Pages 5-7 |
| Data sources/measurement | 8* For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Pages 5-7 |
| Bias | 9 Describe any efforts to address potential sources of bias | Lines 132-135, Page 5 |
| Study size | 10 Explain how the study size was arrived at | Lines 132-135, Page 5 |
| Quantitative variables | 11 Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Lines 190-193, Page 7 |
| Statistical methods | 12 (a) Describe all statistical methods, including those used to control for confounding | Lines 190-197, Page 7 |
| | (b) Describe any methods used to examine subgroups and interactions | |
| | (c) Explain how missing data were addressed | NA |
| | (d) If applicable, describe analytical methods taking account of sampling strategy | NA |
| | (e) Describe any sensitivity analyses | NA |
Results

Participants 13*

(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed

(b) Give reasons for non-participation at each stage

(c) Consider use of a flow diagram

Descriptive data 14*

(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders

(b) Indicate number of participants with missing data for each variable of interest

Outcome data 15*

Report numbers of outcome events or summary measures

Main results 16

(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included

(b) Report category boundaries when continuous variables were categorized

(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

Other analyses 17

Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Discussion

Key results 18

Summarise key results with reference to study objectives

Limitations 19

Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias

Interpretation 20

Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence

Generalisability 21

Discuss the generalisability (external validity) of the study results

Other information

Funding 22

Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for exposed and unexposed groups.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.
Figure 1: Structure coefficient of canonical factors among nursing undergraduates

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; SDL: Self-directed learning

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| Item No | Recommendation | Page/line numbers |
|--------|----------------|-------------------|
| **Title and abstract** | 1. (a) Indicate the study’s design with a commonly used term in the title or the abstract  
(b) Provide in the abstract an informative and balanced summary of what was done and what was found | Lines 1-3, Page 1 |
| **Introduction** | Background/rationale | 2. Explain the scientific background and rationale for the investigation being reported | Pages 3-4 |
| Objectives | 3. State specific objectives, including any prespecified hypotheses | Lines 112-117, Page 4 |
| **Methods** | Study design | 4. Present key elements of study design early in the paper | Line 124, Page 5 |
| Setting | 5. Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Line 124, Page 5 |
| Participants | 6. (a) Give the eligibility criteria, and the sources and methods of selection of participants | Lines 124-131, Page 5 |
| Variables | 7. Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Pages 5-7 |
| Data sources/measurements | 8. For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Pages 5-7 |
| Bias | 9. Describe any efforts to address potential sources of bias | Lines 132-135, Page 5 |
| Study size | 10. Explain how the study size was arrived at | Lines 132-135, Page 5 |
| Quantitative variables | 11. Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Lines 190-193, Page 7 |
| Statistical methods | 12. (a) Describe all statistical methods, including those used to control for confounding  
(b) Describe any methods used to examine subgroups and interactions  
(c) Explain how missing data were addressed  
(d) If applicable, describe analytical methods taking account of sampling strategy  
(e) Describe any sensitivity analyses | Lines 190-197, Page 7 |
| **Results** | Participants | 13. (a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed  
(b) Give reasons for non-participation at each stage  
(c) Consider use of a flow diagram | Lines 203-206, Page 7; Table 1 |
| Descriptive data | 14. (a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders  
(b) Indicate number of participants with missing data for each variable of interest | Lines 203-206, Page 7; Table 1  
Line 203, Page 7; Table 1 |
Outcome data

15*

Report numbers of outcome events or summary measures

Line 203, Page 7; Table 1

Main results

16

(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included

Pages 8-9

(b) Report category boundaries when continuous variables were categorized

NA

(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period

NA

Other analyses

17

Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses

Pages 8-9

Discussion

Key results

18

Summarise key results with reference to study objectives

Lines 256-258, Page 9; Lines 266-268, Page 10; Lines 303-311, Page 11

Limitations

19

Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias

Lines 361-372, Page 13

Interpretation

20

Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence

Pages 10-13

Generalisability

21

Discuss the generalisability (external validity) of the study results

Lines 374-376, Page 13

Other information

Funding

22

Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

Lines 404-406, Page 14

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.
The association of learning environment and self-directed learning ability among nursing undergraduates—a cross-sectional study using canonical correlation analysis

| Journal:       | BMJ Open       |
|---------------|----------------|
| Manuscript ID | bmjopen-2021-058224.R2 |
| Article Type: | Original research |
| Date Submitted by the Author: | 27-Jul-2022 |
| Complete List of Authors: | Tang, Li-qing; Wannan Medical College Zhu, Li-jun; Wannan Medical College Wen, Li-ying; Wannan Medical College Wang, An-shi; Wannan Medical College Jin, Yue-long; Wannan Medical College Chang, Wei-wei; Wannan Medical College, |
| Primary Subject Heading: | Medical education and training |
| Secondary Subject Heading: | Medical education and training, Medical management, Nursing, Public health |
| Keywords: | PUBLIC HEALTH, Epidemiology < ONCOLOGY, MEDICAL EDUCATION & TRAINING |
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The association of learning environment and self-directed learning ability among nursing undergraduates-a cross-sectional study using canonical correlation analysis

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ABSTRACT

Objectives: This study explores the relationship between the perception of the learning environment and self-directed learning (SDL) ability among nursing undergraduates.

Design, setting, and participants: A cross-sectional study was conducted in December 2020 with 1,096 junior and senior undergraduate nursing students (aged 16–22) from Wannan Medical College in Anhui Province, China.

Outcome measures: The Chinese version of the Dundee Ready Educational Environment Measure questionnaire and a validated Chinese version of college students’ SDL ability scale were used to assess students’ perceptions about their learning environment and their SDL ability. Canonical correlation analysis was performed to evaluate their correlation.

Results: The total score for the learning environment was 120.60 (scoring rate: 60.30%), and the score for SDL ability was 89.25 (scoring rate: 63.75%). Analysis indicated that the first canonical correlation coefficient was 0.701 and the contribution rate was 94.26%. The perception of the learning environment was mainly determined by students’ perception of learning (SPL) and academic self-perceptions (SASP), with SDL ability mainly determined by self-management ability and cooperative learning ability. SPL and SASP were positively correlated with self-management ability and cooperative learning ability. Multiple linear regression analysis revealed that SPL, SASP, SPA, and students’ social self-perceptions (SSSP) had a significant impact on SDL ability.

Conclusions: The SDL ability of nursing undergraduates was not high. SPL and SASP were positively correlated with self-management ability and cooperative learning ability. Nursing educators can improve students’ SDL ability by changing their learning environment, using, for example, new student-centered teaching methods.

Key words Perception; Learning environment; Self-directed learning; Nursing; Students
Strengths and limitations of this study

1. This is the first study to explore the correlation between learning environment and SDL ability among nursing undergraduates in China.

2. An advanced statistical method (Canonical Correlation Analysis) was used to evaluate the reportedly unexplored relationship between the multiple dimensions of learning environment and self-directed learning.

3. A cross-sectional study approach was adopted and causality cannot be clearly proven.

4. The nursing undergraduates come from one medical college in western Anhui Province in China and the nationwide generalizability was limited.
INTRODUCTION

Self-directed learning (SDL) refers to an individual’s the initiative in judging their learning needs, establishing their learning goals, selecting and implementing appropriate learning strategies, and evaluating learning outcomes, with or without help from others.[1] SDL ability is a form of comprehensive ability that students exhibit in the process of learning.[2] Nursing is an applied discipline that requires students to have a strong skillset and is closely related to life safety and health interests.[3] Clinical nursing is a profession that requires rapid knowledge updates and lifelong learning.[4] Nursing staff need to continuously learn new knowledge and new technologies. Reliance on the knowledge learned during school is insufficient to meet clinical needs, and nursing staff are required to strengthen their SDL ability to adapt to the rapid updating of nursing knowledge. To adapt to the ever-changing social healthcare needs, the cultivation of senior nursing talents who can independently acquire knowledge has become the main goal and task of training talents for higher nursing education.[5] Good SDL ability is the foundation of lifelong learning for nursing undergraduates.[6] Research in China has revealed that the awareness of SDL ability among nursing undergraduates is weak, and many nurses also regard learning as a burden outside of work.[7-9] The formation of SDL ability does not happen overnight, so it is particularly important to cultivate SDL ability as part of nursing education in college.[10]

The education environment is everything that happens inside a university, including the learning environment, perception of infrastructure, interaction between students and classmates, teachers’ attitudes and skills, and many other related factors.[11] Students’ perception of the educational environment plays a subtle role in learning and contributes positively to learning input and students achievement, which can stimulate students’ interest in learning and affect their motivation.[12-14] Understanding students’ perception of the learning environment also helps improve the quality of learning.[15] The Dundee Ready Education Environment Measure (DREEM) is an educational tool based on a questionnaire survey that can be used to “quantify” the educational environment.[16] It has been translated into a variety of languages and has been used worldwide.[17-19] An educational experiment in an Iranian medical sciences university revealed that DREEM helps to reduce students’
Cognitive deficiencies in many aspects of the educational environment and to identify problems that hinder their improvement.[20]

A survey of nursing and emergency medical services majors at King Saud University showed that a supportive learning environment, including good teaching, clear goals and standards, appropriate assessment, appropriate workload, and emphasis on independence, encouraged students to participate in the SDL process, consequently improving their academic performance.[21] Padugupati et al. found that a flipped classroom learning environment was a dynamic and more social space that could effectively improve students’ learning behavior, including deep learning, self-efficacy, and SDL.[22] A mixed approach study involving Indian medical students highlighted that, given the importance of SDL in medicine, curriculum design should increase learning activities to promote SDL and provide strategies to make the learning environment more conducive to SDL.[23] At present, the formed educational environment in Chinese colleges and universities is not conducive to the cultivation and development of students’ SDL ability.[24] The use of advanced and effective educational methods to create a harmonious and adaptable learning environment so that nursing students can master medical knowledge and clinical skills proficiently while at the same time having a good sense of SDL has become an urgent issue for colleges and universities.

This study investigated the correlations between learning environment and SDL ability among nursing undergraduates. The first purpose of the study was to understand students’ perceptions of the learning environment and the levels of SDL ability. The learning environment and SDL ability are multidimensional, and therefore it is difficult to directly evaluate the relationship between them. And that canonical correlation analysis is a multivariate statistical method, which has been widely used to study the associations between two sets of variables.[25] Therefore, the second purpose of the study was to evaluate the relationship between learning environment and SDL ability by using canonical correlation analysis. This is of great significance for exploring the educational reform plan to improve the SDL ability of nursing undergraduates.
METHODS

Study designs and participants

The study was a cross-sectional descriptive survey conducted in December 2020. The participants were junior and senior undergraduate nursing students from Wannan Medical College in Anhui Province, China. Undergraduate nursing education lasts three years and is divided into two years basic sciences and clinical medicine education and one year internship. The school’s nursing program is composed of three grades; each grade has 20 classes, and each class has 25-33 students. As the students in grade 3 are interns, no questionnaire survey was conducted with them. All students in grades 1 and 2 (1,150 students) participated in the field survey.

The trained investigators distributed questionnaires to students in class. After the investigators read out the unified guidance and told the students to fill in the precautions, the students completed the questionnaire anonymously in the classroom, and the investigators took back the questionnaire on site. Informed consent was obtained and anonymity was ensured from all the participants. Finally, 1,096 respondents were included in the final analysis (response rate: 1,096/1,150=95.30%). Ethical approval for this study was granted by the Ethics Committee of Wannan Medical College (LL-2020BH2086).

Instruments

The self-designed questionnaire included three parts: sociodemographic characteristics, learning environment, and SDL ability.

Demographic characteristics

Demographic variables include gender (male, female), age, grade (first grade, second grade), and birthplace (countryside, town).

Chinese version of the Dundee Ready Educational Environment Measure (DREEM)

The Chinese version of the DREEM survey, translated by the medical education research center of China Medical University, was used to assess students’ perception of their learning environment.[26] This scale contains 50 items, of which nine are reverse-scored. Each item is scored on a five-point Likert scale from 0 (strongly disagree) to 4 (strongly agree). The DREEM inventory has 5 sub-scales: students’ perceptions of learning (SPL; 12 items; e.g., “I
am encouraged to participate in class,” “Long-term learning is emphasized over short-term learning”); students’ perceptions of teachers (SPT; 11 items; e.g., “The teachers are knowledgeable,” “The teachers give clear examples”); students’ academic self-perceptions (SASP; 8 items; e.g., “Much of what I have to learn seems relevant to a career in health care,” “My problem-solving skills are being well developed”); students’ perceptions of atmosphere (SPA; 12 items; e.g., “The atmosphere is relaxed during consultation teaching,” “The atmosphere motivates me as a learner”); and students’ social self-perceptions (SSSP; 7 items; e.g., “I have good friends in this school,” “I seldom feel lonely”). The total DREEM score is calculated by adding the sum score of five sub-scales (total score range: 0-200). Calculation of average scoring rate (%): the actual score of the sub-scale is divided by the full score of the sub-scale. The higher the score rate, the better the learning environment. The DREEM has good validity and has been widely used among college students in China.[27, 28] Cronbach’s alpha values of SPL, SPT, SASP, SPA, and SSSP was 0.818, 0.864, 0.786, 0.834, and 0.675 in this study, respectively.

**Self-directed learning (SDL) Ability**

SDL ability was measured by a validated Chinese version of college students’ Self-directed Learning Ability Scale.[29] This scale contains 28 items, of which five are reverse-scored and each item is rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The scale includes three dimensions: (1) self-management ability, 10 items including the ability to determine learning needs, time management ability and learning monitoring ability (e.g., “I often set learning goals”); (2) information capability, 11 items including information acquisition ability and information analysis and processing ability (e.g., “It is difficult for me to grasp the key points in my study”); and (3) cooperative learning ability, 7 items including the ability to communicate and ask for help (e.g., “When other student ask me for my learning experience, I can always say one or two points”). The total score of SDL ability is the sum of the score for each item (total score range: 0-140). A higher score indicated a higher ability of SDL. Calculation of average scoring rate (%): the actual score of the sub-scale is divided by the full score of the sub-scale. In present study, Cronbach’s $\alpha$ for self-management ability, information capability, and cooperative learning ability subscale was...
0.802, 0.709, and 0.764, respectively.

Patient and public involvement
None.

Data Analysis
The statistical analysis was performed by SPSS 25 for Windows. Scores for total and each domain were expressed as mean ± standard deviation (SD). Categorical variables (e.g., gender, grade etc.) were expressed as frequencies or percentage. Pearson’s correlation coefficients were calculated to examine the correlation between the learning environment and SDL ability. Canonical correlation analysis was used to analyze the correlation between learning environment and SDL ability. Each dimension of learning environment is taken as X group variables, the corresponding typical variable is U. Each dimension of SDL ability is taken as group Y variables and the corresponding typical variable as V. A multiple linear regression analysis was used to analyze the effect of learning environment on SDL ability among nursing undergraduates. A value of \( P < 0.05 \) (two-tailed) was considered statistically significant.

RESULTS

Characteristics Description
Among the 1,096 nursing students in this study, 462 were freshmen and 634 were sophomores. The overall mean age was 19.34 ± 1.09 years (range: 16-22 years). In terms of gender, females accounted for 79.65% of the total respondents, and males 20.35%. Only 46.35% of students would plan to pursue their major in the future. Other basic information of 1,096 students was listed in Table 1.

The overall DREEM mean score was 120.60 (60.30%) of a maximum score of 200, indicating a relative overall satisfaction with the environment but with room for improvement (Table 2). According to sub-scale, the mean score was 29.01 ± 6.46 for SPL (60.43%), 28.63 ± 6.27 for SPT (65.07%), 17.81 ± 4.54 for SASP (55.66%), 28.92 ± 6.42 for SPA (60.25%), and 16.25 ± 3.80 for SSSP (58.04%) domains. The average scoring rate of SASP (55.66%) is relative lower in all dimensions, followed by SSSP (58.04%) (Table 2).

The overall SDL ability mean score was 89.25 (63.75%) of a maximum score of 140. According to sub-scale, the mean score was 32.81±5.56 for self-management ability (65.62%),
34.71±4.47 for information capability (63.11%), and 21.73 ± 3.65 for cooperative learning ability (62.09%) (Table 3).

Correlations between the learning environment and SDL ability

Pearson’s Correlation

The total DREEM scores were positively related with the total score of SDL ability (r=0.680, P<0.001). Similarly, all sub-scale scores of DREEM were positively related with three dimensions of SDL ability (P<0.001, Table 4). It was worth noting that the correlation coefficients between learning environment and SDL ability scores were above 0.4 in all sub-scales, indicating a moderate level of correlation between them.

Canonical Correlation

For the canonical correlation analysis, the X variables represented DREEM (X1 = SPL, X2 = SPT, X3 = SASP, X4 = SPA, and X5 = SSSP) and the Y variables represented SDL ability (Y1 = Self-management ability, Y2 = Information capability, and Y3 = Cooperative learning ability). Three pairs of typical variables were extracted from the results of canonical correlation analysis, and the correlation coefficients of the first two pairs (0.701 and 0.221, respectively) were statistically significant (P < 0.05, Figure 1). The cumulative contribution rate of the first typical variables has reached 94.26% (Table 5). Therefore, this study took the first typical variable for explanation.

In canonical correlation analysis, the absolute value of standardization coefficient represents the weight. The standardized linear functions of the first pair of typical variables are listed as follows: U1(DREEM) = -0.377X1 + 0.094X2 - 0.350X3 - 0.212X4 - 0.240X5; V1(SDL ability) = -0.470Y1 - 0.299 Y2 - 0.357Y3 (Table 6).

U1 mainly determined by X1 (students’ perception of learning, SPL) and X3 (students’ academic self-perceptions, SASP), and V1 mainly determined by Y1 (self-management ability) and Y3 (cooperative learning ability). Further typical structural analysis showed that X1 and X3 were negatively correlated with U1, Y1 and Y3 were negatively correlated with V1. Therefore, SPL and SASP are positively correlated with self-management ability and cooperative learning ability.

Multiple linear regression analysis of educational environment on SDL ability among
nursing students

In multiple linear regression analysis, the total score of SDL ability was defined as the dependent variable and scores on 5 dimensions of educational environment were defined as independent variables. After adjusting gender, age, class, birthplace, and professional choice, the analysis showed positive significant relationships between score of SDL ability and SPL score ($\beta=0.263$, $P<0.001$); SASP score ($\beta=0.245$, $P<0.001$); SPA score ($\beta=0.153$, $P=0.002$) (Table 7).

DISCUSSION

The score rates for self-management ability (65.62%), information capability (63.11%), and cooperative learning ability (62.09%) were all just above 60%, indicating that the SDL ability of nursing undergraduates was not high. The highest score rate was for self-management ability, which was consistent with the results in previous studies.[30,31] This may be related to the fact that the nursing undergraduates were mainly females, and they had better self-planning and self-management for learning. Females’ management learning goals are significantly more positive than males’, because they use more learning self-regulation strategies and display a more positive learning attitude.[32] Other studies have shown that females have clear learning goals, strong learning motivation, and a strong ability to monitor their learning.[33]

The total score for the learning environment was 120.60, with a scoring rate of 60.30%, indicating “a more positive than negative” perception of the environment among nursing undergraduates. The students were generally satisfied with the learning environment. Similarly, the results of two studies conducted in China and India revealed scores of 121.95/200 and 119/200, respectively.[34, 35] The nursing undergraduates had the highest rate for SPT and the lowest rate for SASP, similar to the findings of Gong et al.[36] This may be related to the teaching reforms in the schools attended by the participants, including a significant adjustment to teaching content and methods in recent years.[37, 38] In terms of teaching courses, the case teaching and video teaching in our school (Wannan Medical College) provide students with more opportunities to communicate with teachers.[39] However, SASP had the lowest score rate, followed by SSSP, for all participants. This may be explained by the fact that the students have been engaged in passive receptive learning and...
rely on mechanical memory, an inefficient learning technique of rote memorization, to cope with the exams.[40] As a result, the academic nature of learning has not been developed. In addition, self-generation of knowledge can activate deeper cognitive processing and improve long-term retention compared to the passive reception of information.[41] It can enable students to not only acquire content knowledge but also an understanding of inquiry skills.[41]

Some new teaching models focus on cultivating students’ SDL and in-depth learning rather than rote learning, which is conducive to improving the quality of teaching and promoting the development of education.[42] Sahu et al. reported that the SSSP significantly correlates with subjective happiness and suggested that institutions should promote not only students’ academic development but also their happiness by fostering an appropriate educational environment.[43] Although the scores for all subscales indicated positive perceptions among nursing students, there is a need for improvement in all five domains of the learning environment, particularly in the SASP subscale. One possible reason is the individuals’ perceptions and misperceptions of their academic ability. If people could accurately judge their own abilities, then self-perception would play an important role in the acquisition of education and skills. In order to cultivate the SDL ability of nursing students, the focus in improving the learning environment should be included in the academic perception domain.

To the best of our knowledge, this is the first study to explore the correlation between learning environment and SDL ability among nursing undergraduates. The results of the linear correlation analysis revealed that subscales of the learning environment were positively correlated with those of SDL ability among nursing students, indicating that students with higher scores for learning environment have a better SDL ability. The environment is a major stimulus, providing a strong driving force for educational objects. As we all know, an educational environment affects students’ achievements, happiness, motivation, and success. Sayed et al. showed that a collaborative, academic, and supportive environment might increase the participation of nursing students, while an environment of competition, pressure, or threats might reduce their motivation to learn and weaken their interests in the learning process.[44] Studies have shown that an SDL environment will produce a learner who is self-directed, which can be a contributing factor to enhancing that individual’s quality of life or in learning.[45] In addition, students’ motivation and opportunities for the development of
deep understanding are important in creating a positive self-directed learning experience, which can affect SDL ability.\cite{46} In recent years, colleges and universities have devoted considerable attention to developing educational programs to promote the self-directed learning capacity necessary to prepare students for lifelong learning. However, traditional academic structures may not effectively promote SDL, and there is growing recognition of the importance of an academic climate or environment for students to learn effectively.\cite{22, 23, 47, 48} Our findings suggest that students’ SDL ability can be improved by changing their learning environment, such as a new student-centered teaching method. One survey of 4,257 college students in research universities demonstrated that effective instructor facilitation can influence both students’ self-assessment of learning and their perceived utility of the learning activities, and can improve SPL by improving teachers’ teaching ability.\cite{49} Some studies have highlighted that psychological distress and low peer social support work together to reduce medical students’ SASP.\cite{50} Furthermore, a multi-wave longitudinal study of Chinese children demonstrated that contributions by SASP to achievement occurred in a progressive, cascading manner.\cite{51} Therefore, it is suggested that steps should be taken to cultivate positive psychological states and students’ sense of achievement to improve SASP. SPL and SASP are positively correlated with self-management ability and cooperative learning ability, suggesting that nursing students with a better perception of learning and academia have a stronger self-management ability and stronger cooperative learning. The above results indicate that changing some aspects of the learning environment can significantly improve the learning enthusiasm and initiative of nursing undergraduates.

The canonical correlation analysis indicated that the learning environment was mainly determined by SPL and SASP, and SDL ability was mainly determined by self-management ability and cooperative learning ability. And then, SPL and SASP are positively correlated with self-management ability and cooperative learning ability, suggesting that students’ self-management ability and cooperative learning ability can be improved by changing the environment of SPL and SASP, so as to improve SDL ability. Students reporting high satisfaction with the learning environment have a high sense of happiness, which can improve students’ passion for learning.\cite{52} Teachers can improve students’ perception of the learning
environment by changing traditional teaching methods to improve students’ SDL ability. Alshawish et al. found that case-based blended teaching can improve students’ perception of the learning environment.[53] Liu et al. revealed that the teaching model combining virtual simulation technology and network teaching can effectively cultivate the “student-centered” autonomous learning ability and promote the development of nursing students’ autonomous inquiry learning behavior.[54] To actively participate in classroom teaching and master the knowledge points of learning, students consciously engage in pre-class and post-class reviews, which can improve their self-management ability.[55] Zu et al. changed the nursing education environment using a case teaching method and fully mobilized students’ interest in autonomous learning.[56] Therefore, teachers should constantly explore new education and teaching methods (such as flipped classroom, seminar and problem-based learning) to stimulate nursing students’ learning enthusiasm and promote them to adopt in-depth learning methods, so as to achieve the purpose of ability training.[57]

When nursing undergraduates who have a high thirst for knowledge and actively participate in classroom teaching encounter difficulties in the learning process, they will acquire knowledge through communication and exchange with classmates and teachers, reflecting their good learning and cooperation abilities.[58,59] A quasi-experimental study concluded that a training program based on maker education improved students’ creativity, learning interest, and cooperative learning ability.[60] The learning environment directly affected students’ learning methods and academic achievements, and satisfaction with the learning environment could in turn encourage students to adopt a more positive approach to learning.[61] Therefore, to improve the SDL ability of nursing students, it is indispensable to create an adaptive learning environment. Comparatively strong infrastructure, experienced faculty, competent administration, and leadership, as well as an environment that is student-friendly might have contributed to a better learning environment.[62] Universities and colleges have been faced with the daunting task of having to grapple with the inevitable change by re-adjusting and reorganizing themselves in preparation for the transformation and reconstruction of the traditional higher education model.[63] We suggest the following measures, first, the instructional process is personalized in terms of different instructional
parameters such as sequence of tasks and task difficulty, time and type of feedback, pace of
learning speed, reinforcement plan, and so on. Second, the school can provide more social and
the communication opportunity for the nursing undergraduate student in education and
teaching. The teachers guide the nursing undergraduates to use the new social platform to
strengthen the unity and build a good interpersonal relationship and communication
environment. Third, teacher- centeredness in the teaching process should be changed, and
nursing students should be placed at the center of education.[64] Hong et al. revealed that the
application of the combination model of Small Private Online Course and Objective
Structured Clinical Examination in pediatric nursing training teaching was conducive to
stimulate students’ learning interest and improve students’ professional comprehensive ability,
including interpersonal communication ability.[65] Teachers should therefore adopt
exploratory and innovative teaching methods to change the learning role of nursing students
based on “listening and memorizing.” Moreover, to improve students’ SDL ability, teachers
should maximize the enthusiasm and initiative of nursing students in learning. [66,67]

LIMITATIONS

When interpreting the findings of this study, some limitations should be taken into account.
First, a cross-sectional study approach was adopted and causality cannot be clearly proven.
Second, all information was obtained from self-reported questionnaires, which may lead to
recall and reporting bias. Third, the nursing undergraduates came from one medical college in
western Anhui Province and the nationwide generalizability was still limited. A
muti-institutional design from more areas is highly prioritized in the follow-up research.
Finally, this study adopted a single quantitative data survey method. Qualitative data derived
from focus groups could help explore how nursing students approach self-directed learning,
what they value in the learning environment, and why self-perception of academic
performance scores was low. A mixed-method study (qualitative interview and quantitative
survey) is highly prioritized in the follow-up research.

CONCLUSION

In summary, the SDL ability of nursing undergraduates was not high. SPL and SASP are
positively correlated with self-management ability and cooperative learning ability. Nursing
educators can improve students’ SDL ability by changing their learning environment to include new student-centered teaching methods. A multi-institutional and mixed-method design based in other areas should be highly prioritized in follow-up research.

**Abbreviations**

DREEM: Dundee Ready Educational Environment Measure; SPL: Students’ Perceptions of Learning; SPT: Students’ Perceptions of Teachers; SASP: Students’ Academic Self-Perceptions; SPA: Students' Perceptions of Atmosphere; SSPP: Students’ Social Self-Perceptions; SD: Standard Deviation; SDL: Self-directed learning

**Acknowledgments** The authors thank all the participating students for their willingness to complete the questionnaires. We would like to thank the editors of this manuscript and Editage (www.editage.cn) for English language editing.

**Contributors** TLQ and CWW: Writing-original draft, preparation, Investigation. CWW, ZLJ, WLY and WAS: Writing-review & editing. CWW and JYL: Conceptualization, Methodology, Supervision. All authors read and approved the final manuscript.

**Competing interests** None declared.

**Funding** This work was supported by the projects of Anhui Province Quality Engineering (2020jyxm2086; 2015zjjh017); Talent Project of Education Department of Anhui Province (gxyqZD2017066), and Talents Program for Academic Leaders and Reserve Candidates of Wannan Medical College (No. School Administration Letter [2021] No. 46); Wannan Medical College Quality Project (2020jyxm18).

**Patient and public involvement** None.

**Patient consent for publication** Not applicable.

**Ethics approval** This study was approved by the Ethics Committee of Wannan Medical College (LL-2020BH2086). Written informed consent forms were obtained from the subjects that participated in this study.

**Data availability statement** Data are available upon reasonable request.
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Table 1 Demographic characteristics of the participants (n=1,096)

| Variables                  | Category       | Frequency | Percentage (%) |
|----------------------------|----------------|-----------|----------------|
| Gender                     | Male           | 223       | 20.35          |
|                            | Female         | 873       | 79.65          |
| Class                      | Freshman       | 462       | 42.15          |
|                            | Sophomore      | 634.00    | 57.85          |
| Age                        | Mean ± SD: 19.34 ± 1.09, Range (16–22) |           |                |
| Birthplace                 | Countryside    | 802       | 73.18          |
|                            | Town           | 294       | 26.82          |
| Do you plan to pursue this major in the future? | Yes | 508 | 46.35 |
|                            | No             | 141       | 12.86          |
|                            | Uncertain      | 447       | 40.79          |
| DREEM Domains | Full marks | Mean (SD)   | Average scoring rate (%) |
|---------------|------------|-------------|--------------------------|
| SPL           | 48         | 29.01(6.46) | 60.43                    |
| SPT           | 44         | 28.63(6.27) | 65.07                    |
| SASP          | 32         | 17.81(4.54) | 55.66                    |
| SPA           | 48         | 28.92(6.42) | 60.25                    |
| SSSP          | 28         | 16.25(3.80) | 58.04                    |
| Total DREEM score | 200 | 120.60(24.72) | 60.30                    |

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions
Table 3 Mean (SD) subscale and total score of SDL ability for nursing undergraduates

| Sub-scales                  | Full marks | Mean (SD)     | Average scoring rate (%) |
|-----------------------------|------------|---------------|--------------------------|
| Self-management ability     | 50         | 32.81 (5.56)  | 65.62                    |
| Information capability      | 55         | 34.71 (4.47)  | 63.11                    |
| Cooperative learning ability| 35         | 21.73 (3.65)  | 62.09                    |
| Total score                 | 140        | 89.25 (12.12) | 63.75                    |
Table 4 Pearson’s correlation coefficients between learning environment and SDL ability among nursing undergraduates

| Sub-scales | Self-management ability | Information capability | Cooperative learning ability | Total score |
|------------|-------------------------|------------------------|----------------------------|-------------|
| SPL        | 0.608**                 | 0.549**                | 0.555**                    | 0.648**     |
| SPT        | 0.532**                 | 0.427**                | 0.411**                    | 0.525**     |
| SASP       | 0.565**                 | 0.529**                | 0.585**                    | 0.630**     |
| SPA        | 0.590**                 | 0.546**                | 0.546**                    | 0.636**     |
| SSSP       | 0.574**                 | 0.520**                | 0.565**                    | 0.625**     |
| Total DREEM score | 0.639**                 | 0.570**                | 0.585**                    | 0.680**     |

**There was a significant correlation at 0.01 level (bilateral)**
Table 5 Outcomes of canonical correlation analysis and likelihood ratio test

|   | Correlation | Proportion (%) | Cumulative | F     | P     |
|---|-------------|----------------|------------|-------|-------|
| 1 | 0.701       | 94.26          | 94.26      | 61.110| <0.001|
| 2 | 0.221       | 4.96           | 99.22      | 7.976 | <0.001|
| 3 | 0.087       | 0.78           | 100.00     | 2.754 | 0.041 |
Table 6 Standardized coefficients of the first and second pairs of typical variables

| SDL ability | Variables                      | typical variable 1 | typical variable 2 |
|-------------|--------------------------------|--------------------|--------------------|
| DREEM (X)   | SPL (X1)                        | -0.377             | -0.122             |
|             | SPT (X2)                        | 0.094              | 1.467              |
|             | SASP (X3)                       | -0.350             | -0.491             |
|             | SPA (X4)                        | -0.212             | -0.160             |
|             | SSSP (X5)                       | -0.240             | -0.443             |
| SDL ability (Y) | Self-management ability (Y1)  | -0.470             | 1.287              |
|             | Information capability (Y2)     | -0.299             | -0.004             |
|             | Cooperative learning ability (Y3)| -0.357             | -1.309             |
Table 7 Multiple linear regression analysis of educational environment on SDL ability among nursing students

| Independent variables | B     | SE  | β    | t     | P*   |
|-----------------------|-------|-----|------|-------|------|
| Constant              | 48.820| 2.659| 18.360| <0.001|
| SPL                   | 0.493 | 0.095| 0.263| 5.208 | <0.001|
| SPT                   | -0.140| 0.079| -0.073| -1.780| 0.075|
| SASP                  | 0.654 | 0.098| 0.245| 6.695 | <0.001|
| SPA                   | 0.289 | 0.092| 0.153| 3.141 | 0.002|
| SSSP                  | 0.535 | 0.126| 0.168| 4.253 | <0.001|

*The adjustment factors: gender, age, class, birthplace, and planning to pursue this major in the future. SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; B: unstandardized coefficient; SE: standard error; β: standardized coefficient.
Figure legend/caption

Figure 1 Structure coefficient of canonical factors among nursing undergraduates

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; SDL: Self-directed learning
Figure 1 Structure coefficient of canonical factors among nursing undergraduates

SPL: Students’ Perception of Learning; SPT: Students’ Perception of Teaching; SASP: Students’ Academic Self-Perceptions; SPA: Students’ Perceptions of Atmosphere; SSSP: Students’ Social Self-Perceptions; SDL: Self-directed learning
# STROBE Statement—Checklist of items that should be included in reports of cross-sectional studies

| Item No | Recommendation | Page/line numbers |
|---------|----------------|-------------------|
| 1       | (a) Indicate the study’s design with a commonly used term in the title or the abstract | Lines 1-3, Page 1 |
|         | (b) Provide in the abstract an informative and balanced summary of what was done and what was found | Page 2 |
| 2       | Explain the scientific background and rationale for the investigation being reported | Pages 4-5 |
| 3       | State specific objectives, including any prespecified hypotheses | Lines 25-28, Page 5 |
| 4       | Present key elements of study design early in the paper | Line 3, Page 6 |
| 5       | Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection | Line 3, Page 6 |
| 6       | (a) Give the eligibility criteria, and the sources and methods of selection of participants | Lines 4-10, Page 6 |
| 7       | Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable | Pages 6-7 |
| 8*      | For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group | Pages 6-7 |
| 9       | Describe any efforts to address potential sources of bias | Lines 11-15, Page 6 |
| 10      | Explain how the study size was arrived at | Lines 9-10, Page 6 |
| 11      | Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why | Lines 3-4, Page 8 |
| 12      | (a) Describe all statistical methods, including those used to control for confounding | Lines 5-14, Page 8 |
|         | (b) Describe any methods used to examine subgroups and interactions | Lines 5-14, Page 8 |
|         | (c) Explain how missing data were addressed | NA |
|         | (d) If applicable, describe analytical methods taking account of sampling strategy | NA |
(e) Describe any sensitivity analyses  

Results

Participants 13*  
(a) Report numbers of individuals at each stage of study—e.g., numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed  
Lines 17-21, Page 8; Table 1  
(b) Give reasons for non-participation at each stage  
NA  
(c) Consider use of a flow diagram  
NA

Descriptive data 14*  
(a) Give characteristics of study participants (e.g., demographic, clinical, social) and information on exposures and potential confounders  
Lines 17-21, Page 8; Table 1  
(b) Indicate number of participants with missing data for each variable of interest  
NA

Outcome data 15*  
Report numbers of outcome events or summary measures  
Lines 28-29, Page 8; Lines 1-2, Page 9; Table 3

Main results 16  
(a) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included  
Pages 8-10  
(b) Report category boundaries when continuous variables were categorized  
NA  
(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period  
NA

Other analyses 17  
Report other analyses done—e.g., analyses of subgroups and interactions, and sensitivity analyses  
Pages 8-10

Discussion

Key results 18  
Summarise key results with reference to study objectives  
Lines 19-23, Page 10; Lines 18-22, Page 11; Lines 22-27, Page 12

Limitations 19  
Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias  
Lines 16-26, Page 14

Interpretation 20  
Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence  
Pages 10-14

Generalisability 21  
Discuss the generalisability (external validity) of  
Lines 19-21, Page 14

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y the study results

Other information

Funding 22 Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based. Lines16–20, Page15

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.