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RESEARCH

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# Nursing students' knowledge and effectiveness of teaching in infection prevention and control

Stephanie Bouget Mohammedi<sup>1,2,5\*</sup> , Pierre Gillois<sup>2,3,6</sup> and Caroline Landelle<sup>2,4,6</sup>

## Abstract

**Introduction** In order to prevent healthcare-associated infections, infection prevention and control (IPC) is taught to nursing students in France as soon as they enter the nursing training institutes. The primary objective of this study was to assess the knowledge of standard precautions and hand hygiene of French nursing students before and after training. Secondary objectives were to measure factors predicting success on knowledge tests, and to investigate the effectiveness of the different teaching techniques used.

**Materials and methods** A quantitative study using online self-administered questionnaires was performed between September 1, 2022 and March 7, 2023 in French nursing training institutes. Three self-administered questionnaires were administered: the first to IPC trainers on their teaching methods, and the next two to nursing students on their knowledge and socio-demographic characteristics, with one questionnaire before and one after IPC training.

**Results** Fifty-nine nursing training institutes took part in the study. Before and after IPC training, 3,739 and 2,378 nursing students participated, respectively. At the start of training, the mean score on the knowledge test was 35.67 out of 50 ([35.53–35.77]  $sd = 3.76$ ), i.e. a moderate level of knowledge. After IPC training, the mean score on the knowledge test was 37.55 out of 50 ([37.40–37.68]  $sd = 3.48$ ), i.e. a good level of knowledge. Students with a Nursing Auxiliary Diploma (NAD) scored significantly better than no NAD students, both before ( $p < 0.001$ ) and after ( $p < 0.001$ ) IPC training. The teaching techniques used were varied and combined, but only practice audits significantly improved students' knowledge after training ( $p = 0.050$ ).

**Discussion** Nursing students' knowledge of IPC before training is heterogeneous and moderate. After training, knowledge had improved little but significantly. Only auditing was effective to improve students' level of knowledge of IPC. Audits should be included in the IPC training program.

## Highlights

- Nursing students' knowledge of hygiene at the beginning of their training is moderate.
- Students who have previously obtained a nursing auxiliary diploma have a better knowledge of hygiene than other students.
- Student nurses' knowledge of hygiene improves after the first semester of training.

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- Practice audits help to improve students' knowledge of hygiene.

**Keywords** Nursing education, Standard precautions, Hand hygiene, Teaching, Infection prevention and control

## Introduction

Around 5 million healthcare-associated infections (HAIs) occur in European hospitals each year, representing around 25 million additional hospital days and an economic burden of between 13 and 24 billion euros [1]. Mortality attributable to HAIs in Europe is estimated at 1% (50,000 deaths per year) [1]. There are a number of important measures to prevent HAIs: Standard Precautions (SP), and including first and foremost Hand Hygiene (HH). Since 2001, the preferred technique for HH has been hydro-alcoholic friction, and the World Health Organization (WHO) has defined 5 indications for HH [1]. Another SP priority is the use of Personal Protective Equipment (PPE): gloves, masks, goggles and protective clothing (apron, overcoat). PPE are essential for the users' safety but also helps to limit the cross-transmission of micro-organisms [2]. In a context of changing microbial flora and the emergence of new viruses (such as SARS-CoV-2), it is even more important that healthcare professionals and Nursing Students (NSs) are educated about these risks, and that they correctly apply these simple measures, the effectiveness of which is recognized [3, 4].

However, studies in the literature show that NSs' knowledge of Infection Prevention and Control (IPC) is moderate. We have previously identified 36 international studies that assessed the knowledge of NSs [5]. Assessment of HH knowledge was most often carried out using the WHO questionnaire [5]. Six studies showed poor knowledge, 9 studies moderate knowledge and 6 studies good knowledge. SP knowledge was most commonly assessed using the Tavolacci et al. questionnaire. Six studies showed poor knowledge, 9 studies moderate knowledge and 6 studies good knowledge. In France, we have previously shown that the validation rate of IPC teaching by NSs is high, with a pass rate of 91.7% [91.5–91.9], but with an assessment mean of only 12.3 out of 20 (sd = 1.69) [6]. Internationally, nursing education is increasingly developing innovative teaching methods [7, 8]. This is also the case for IPC teaching with e-learning [9, 10], simulation [11] and virtual reality [12]. Multimodal approaches are common in France. On average, trainers use 8 different pedagogical techniques to teach IPC [5]. However, the effectiveness of these different pedagogical techniques in improving NS knowledge has never been evaluated in IPC subject.

The primary objective of this survey was to assess the knowledge of SP and HH of NSs in France at the beginning and at the end of IPC courses. The secondary objectives were to measure the factors predicting success on the knowledge test, to measure progress on the points

knowledge test and to study the most effective teaching techniques.

## Objectives

The main objective was to measure the knowledge of the NSs by cumulating the scores obtained from the WHO and Tavollaci et al. knowledge questionnaires on up to 50 points of the questionnaire before any training and then at the end of the semester. The analysis was based on the mean questionnaire score, confidence intervals [CI95%] and its standard deviation (sd). A score between 37.5 and 50 was considered good, between 25 and 37.4 was considered moderate, and between 0 and 24.9 was considered poor.

The first secondary objective was to measure progress on the point knowledge questionnaire.

The second secondary objective was to measure factors predictive of success on the NSs knowledge questionnaire Before and After using univariate analysis to select influencing variables, followed by multivariate analysis. Success was measured by a 3-class ordinal variable (low, moderate and good) of the total score on the questionnaires, with the low class as the reference. The variables studied were the regions of the NTI, the status of the institute/facility, the age and gender of the NS, the diploma obtained before entering training, the previous activity and the presence of a professional activity in addition to training.

The third secondary objective was to identify the most effective pedagogical techniques by studying the influence of the pedagogy used on the cohort's progression in terms of Before/After knowledge scores, using univariate and then multivariate analyses.

## Materials and methods

### Design of the study

A quantitative study using self-administered online questionnaires on LimeSurvey was conducted between September 1, 2022 and March 7, 2023. The 324 French Nursing Training Institutes (NTI) were invited to participate in this study. Three online questionnaires were developed. The 3 questionnaires were pre-tested and re-adjusted with 5 NSs and 3 volunteer trainers to check that the questionnaire had been properly understood and that the tool was working properly. The results of the pre-tests were not used in the analysis of the results.

### Data collection

The first survey was addressed to for the volunteer IPC director in each NTI between September 1 and 30, 2022.

The link to the questionnaire was sent by e-mail to the secretariat offices or management of all 320 French nursing training institutions (263 public institutes and 57 private non-profit institutes), to be forwarded to a single course coordinator per institute. The structure of the questionnaire included questions on the status of the facility/institute, the region of the institute, the number of NTIs in the graduating class, the number of hours of IPC teaching, the position/status of the teachers running the courses and the teaching methods used. The French country has been divided into 5 major regional groupings: Paris and environs, South-West and Overseas (Nouvelle Aquitaine, Occitanie and Martinique, Guadeloupe, Guyane, Réunion and Mayotte), South-East (Auvergne Rhône Alpes, Provence Alpes Côte d'Azur and Corse), North-West (Bretagne, Pays de la Loire, Centre Val de Loire and Normandie) and North-East (Bourgogne, Franche-Comté, Grand Est and Hauts de France). Sixteen pedagogical techniques were precisely defined (Appendix 1). We also divided data according to 8 pedagogical groups: synchronous/asynchronous, flipped classroom, simulation, quizzes, case studies, pedagogical games, mind mapping, auditing. An open-ended question was asked about needs and suggestions for improvement. All trainer questionnaires collected were included in the descriptive analysis, and only complete trainer questionnaires were included in the multivariate analysis.

Two further surveys were addressed to all volunteer 1st year NSs with the agreement of their NTI management and took place in two phases: before any PCI training, i.e. when they joined the NTI (Before), and after any PCI training, i.e. at the end of the first semester (After). The Before survey took place between September 1 and 30, 2022, and the After survey between January 7 and March 7, 2023. The 2 Before/After questionnaires used to assess NSs knowledge consisted of 5 parts. The first part collected general information on the identification of the NTI, as well as age, gender, last diploma validated before starting the training (general baccalaureate, technological baccalaureate, professional baccalaureate, Nursing Auxiliary Diploma (NAD), other diploma), activity before starting the training (high school students, students in higher education, employed in the health, sanitary or social sector, employed in another sector, not working), a professional activity in parallel to the study in the health sector or in another sector and the number of hours worked per month. A second part contained 7 questions on knowledge of HAIs, a third part included 12 questions on SP and a fourth part included 31 questions on HH. These 50 knowledge questions were of the true/false or multiple-choice type, based on the WHO questionnaire on HH and that of Tavollaci et al. for SP. The maximum possible score for each questionnaire was 25, and each corresponded to a level of knowledge ranging from

poor to very good. Part 5 contained 4 questions open-ended to assess the NSs' satisfaction with the teaching provided. This last part was only included in the end-of-semester survey. Only complete student questionnaires at the beginning of the semester and complete questionnaires excluding the satisfaction questionnaire at the end of the semester were included in the analysis of results. Respondent anonymity was guaranteed and non-mandatory free items were offered in the forms to allow us to track responses from the same students before and after. Duplicates were identified and deleted. Outlier questionnaires were excluded.

### Data analysis

Qualitative variables such as gender or diploma levels, were expressed as absolute numbers and percentages. Quantitative variables such as the WHO Score or age, were described by their mean, CI95%, sd and minimum and maximum values if of interest, or median and interquartile range [Q1-Q3].

In order to analyze the progression of the results and the factors influencing this progression, only NS were included in the study for which the NTI training questionnaire had been completed and for which at least 10 NTIs from the NTI teacher had completed the Before/After questionnaire; unpaired tests were performed. A subgroup analysis of the same students who answered the questionnaire before and after was also carried out by paired tests.

The variables were analyzed according to their type and the chosen combination of variables using Chi<sup>2</sup>, Student and Pearson tests for the parametric approach and Spearman, Wilcoxon if paired and for the 2-group case, Mann-Whitney or Kruskal-Wallis if unpaired for the non-parametric tests for the 2-group case or more than 2-group case respectively. Parametric tests were used when the assumption conditions were validated. The normality of the distribution was verified either by analyzing the distribution graph associated with the Skewness and Kurtosis measure, which had to be between -2 and +2. The significance level was set at 0.05. All statistical tests were two-sided and performed using R version R 4.4.2. The R packages rstatix (version 0.7.2) were used for Kruskal Wallis test.

In addition, the open-ended comments at the end of the IPC referent trainers' questionnaires were analyzed by looking for occurrences of terms in the text.

This survey was a RNIPH (Research Not Involving the Human Person) according to the French research methodology (MR-004) since we are focusing on health education and not human health data.

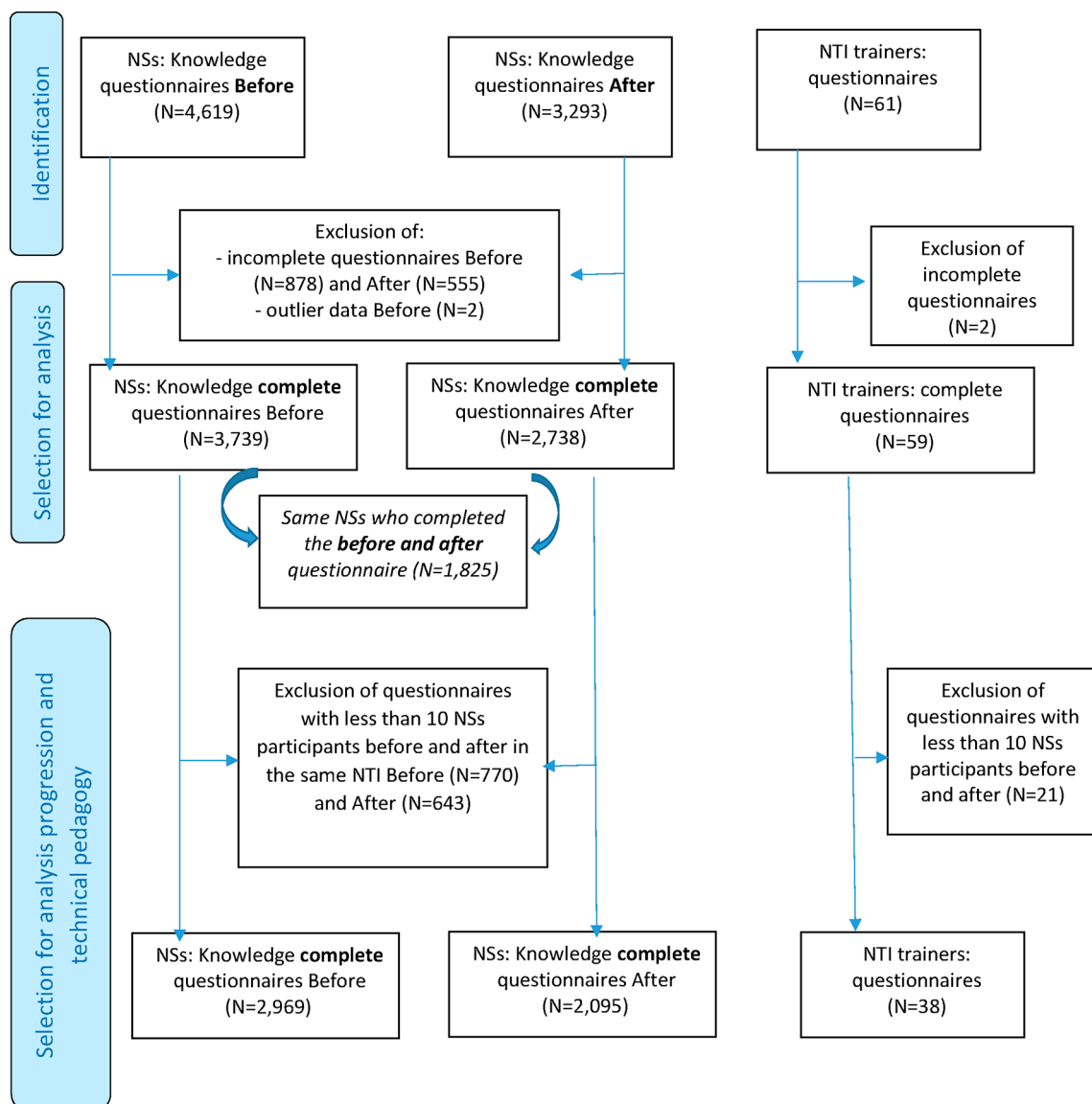
**Results**

**Survey of NTI trainers**

Fifty-nine questionnaires were completed in full (Fig. 1) by IPC referent trainers out of the 324 French NTIs, representing a participation rate of 18.2%. Of these institutes/facilities, 45 (73.8%) were public and 16 (26.2%) private. They came from all over France. The median number of NSs in 1st year was 100 [76–122]. Teaching was provided by a variety of trainers, mainly hygiene nurses (37.9%) from the NTI or from outside, by mainly university lectures (32.8%) and NTI trainers without specific IPC qualifications (29.3%). The median number of teaching hours was 40 h [34.5–40], of which 24 h [19.5–34.5] were face-to-face teaching, 10 h [2–18.5] were distance learning and the rest were personal work. A wide

variety of teaching methods were used (Appendix 2), and several techniques were systematically combined. There were no differences in the teaching methods used according to the region or the status of the institution.

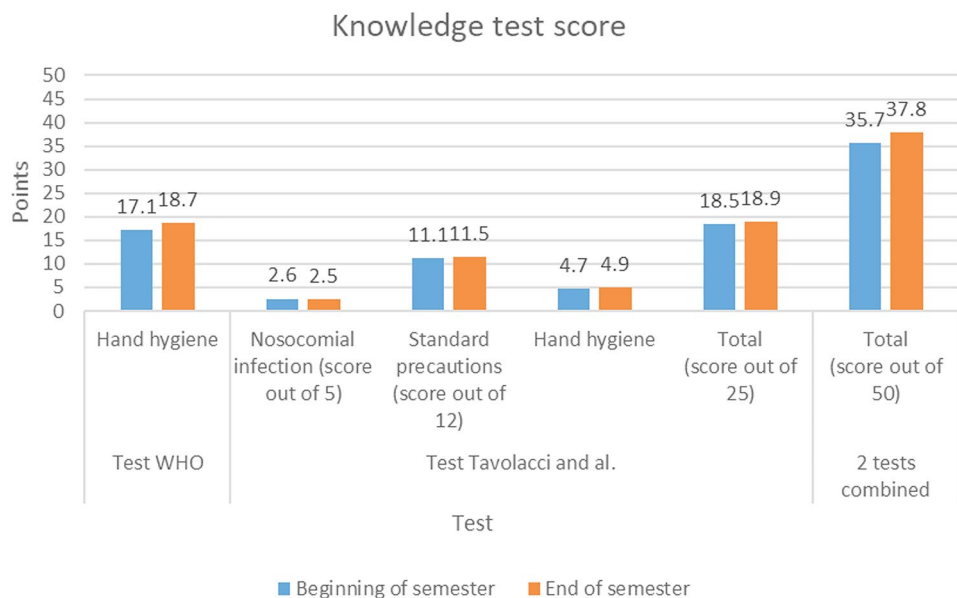
According to the trainers, the aspects that need to be addressed to improve the teaching of IPC are lack of time (42.5%), lack of ready-to-use tools (31.3%), lack of materials (15%) and lack of knowledge (3.7%). The recurrence of needs identified in the transcript of the open questions showed that 10 trainers wanted serious games, 5 wanted escape games, 3 wanted error room scenarios and 2 wanted simulation session scenarios. In addition, 93.2% of them would be very interested in an IPC training kit. Among the proposals for improving IPC teaching, it was



**Fig. 1** Flow chart

**Table 1** Description of the student cohorts who took part in the knowledge tests before/after

		Before N=3,739	After N=2,378
Genre	Women	3,181 (85.1%)	2,048 (86.1%)
	Men	558 (14.9%)	330 (13.9%)
Age (years)	Median age [Q1-Q3]	19 [18–22]	19 [18–22]
	Youngest student's age	16	17
	Age of oldest student	58	60
Activity before starting training	Student	1,885 (50.4%)	1,210 (50.9%)
	Employees in the healthcare or social sector	791 (21.2%)	465 (19.6%)
	Students in higher education	743 (19.9%)	482 (20.3%)
	Employees in another sector	274 (7.3%)	246 (10.3%)
	No activity	46 (1.2%)	33 (1.4%)
Diplomas	General baccalaureate	1,574 (42.1%)	1,008 (42.4%)
	Technological baccalaureate	1,036 (27.7%)	654 (27.5%)
	Professional Baccalaureate	741 (19.8%)	465 (19.6%)
	State diploma in nursing assistance	532 (14.2%)	305 (12.8%)
Salaried activity in parallel with studies	No activity	3,371 (90.2%)	2,149 (90.4%)
	Activity in the health and social sector	187 (5%)	133 (5.6%)
	Activity in another sector	181 (4.8%)	96 (4%)
	Median number of hours per week [Q1-Q3]	14 [9–24]	12 [8–20]



**Fig. 2** a Knowledge test score (N=3,739 Beginning of semester; N=2,378 End of semester). b Level knowledge 2 tests combined (N=3,739 Beginning of semester; N=2,378 End of semester)

suggested that teaching should be spread over the 3 years of training for French NSs.

**NS survey at the beginning of the semester: before**

At the start of IPC training, a total of 3,739 NSs completed the questionnaire in full, and 232 NSs initiated it but did not complete it. This represented 10.4% of the available NTI places. The cohort was predominantly female and young (Table 1). The majority had just completed their baccalaureate, and most of them had studied in a general stream. Of the cohort, 532 (14.2%) had

obtained a NAD before starting their nursing training. In addition to their studies, a few NSs were employed.

The cumulative knowledge questionnaire score for the 2 tests (Fig. 2) was 35.67 out of 50 ([35.53–35.77] sd=3.76). In the WHO HH questionnaire, the score was 17.1 out of 25 ([17.0–17.2] sd=2.73). In the Tavolacci et al. questionnaire, the score was 18.5 out of 25 ([18.4–18.6] sd=1.85), with 2.6 out of 5 ([2.59–2.65] sd=1.03) for HAI, 11.1 out of 12 ([11.1–11.2] sd=1.05) for SP and 4.7 out of 5 ([4.6–4.7] sd=1.11) for HH. The knowledge questionnaire score corresponded to a moderate level of knowledge for 2,509 NSs (67.1%), good for 1,221 NSs

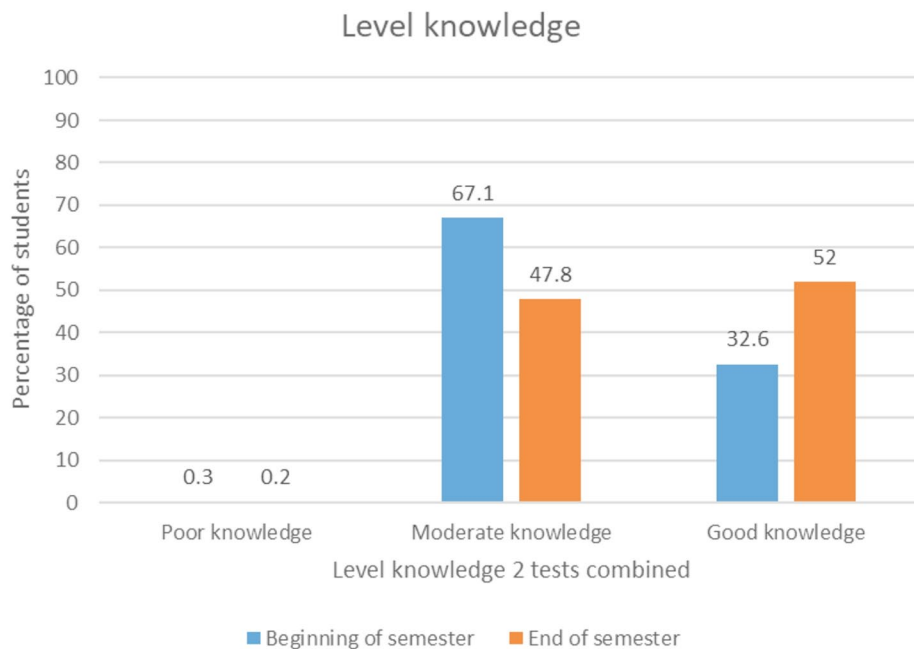


Fig. 2 (continued)

(32.6%) and poor for 11 NSs (0.3%) (Fig. 2). The Before knowledge questionnaire score was correlated with age (Pearson’s Rho = 0.205; p value < 0.001) and with the NAD obtained before the start of training (Student’s t = -12.5; p value < 0.001). Analysis by nonparametric test showed that only NSs with a NAD performed significantly different knowledge test results (Kruskal Wallis; Chi2 = 11.8; p < 0.001, ε<sup>2</sup> = 0.003).

**End-of-semester NS survey: after**

A total of 2,378 NS completed the questionnaire in full, representing 6.6% of the available NSs places. For the After survey, the cohort (Table 1) was again predominantly female and young. The majority had just completed the baccalaureate, and most had a general education background. Of the cohort, 305 (12.8%) had obtained a NAD before entering nursing education. In addition to their studies, a few NS were employed.

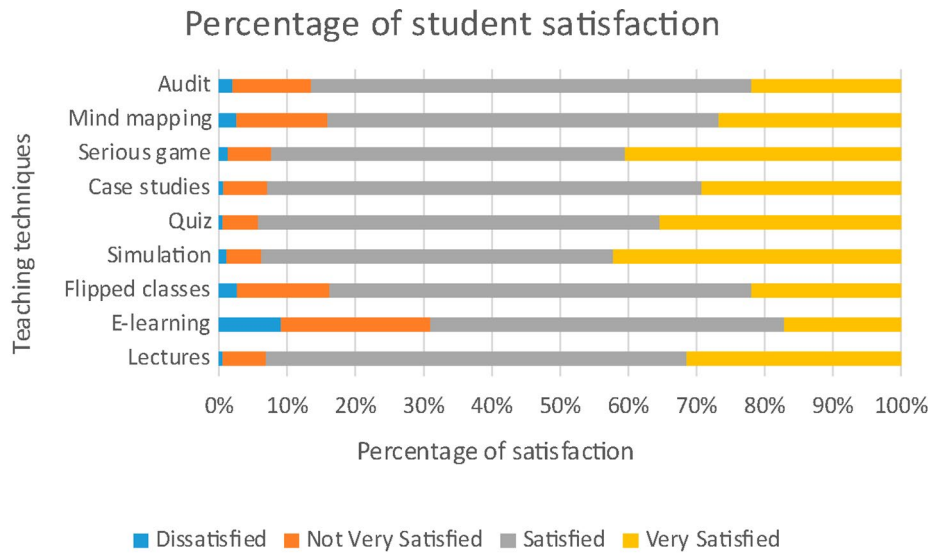
The cumulative score for the 2 knowledge questionnaires (Fig. 2) was 37.55 out of 50 ([37.40–37.68] sd = 3.48). In the WHO HH questionnaire, the score was 18.7 out of 25 ([18.6–18.8] sd = 7.71). In the Tavolacci et al. questionnaire, the score was 18.85 out of 25 ([18.77–18.92] sd = 1.76), with 2.54 out of 5 ([2.50–2.57] sd = 0.95) for HAI, 11.46 out of 12 ([11.42–11.50] sd = 1.00) for SP and 4.85 out of 5 ([4.80–4.89] sd = 1.07) for HH. The knowledge questionnaire score corresponded to a good level of knowledge for 1,236 NSs (52.0%), moderate knowledge for 1,137 NSs (47.8%), and poor knowledge for 5 NSs (0.2%) (Fig. 2). The After knowledge questionnaire score

was correlated with age, with older NSs performing better (Pearson’s Rho = 0.209; p < 0.001). It was correlated with the diploma obtained before starting training: students with an NAD had better results (Chi2 = 38.5; W = -8.77; p < 0.001). Students with a vocational baccalaureate, on the other hand, performed significantly worse than others (Chi2 = 68.1; W = 11.7; p < 0.001). Having worked in the health or social care services sector before starting training led to better results (Chi2 = 74.8; W = -12.2; p < 0.001), while being a high school student at the time of starting training was significantly associated with a lower score (Chi2 = 86.1; W = 13.1; p < 0.001). Analysis by nonparametric test showed that only NSs with a NAD performed significantly different After knowledge test results (Kruskal Wallis; Chi2 = 20.3; p < 0.001, ε<sup>2</sup> = 0.008).

The satisfaction of the NSs with the different teaching techniques was assessed (Fig. 3). Overall, 98.4% of the NSs felt that IPC teaching was relevant to their career plans. The most popular teaching techniques were: quizzes (94.24% satisfied), simulation (93.89%), lectures (93.14%), case studies (92.92%) and educational games (92.36%). The e-learning capsules were much less appreciated, with only 68.95% of NSs satisfied.

**Before/after progress and teaching techniques that influence progress during the semester**

To investigate the factors influencing progress, 38 of the NTIs that responded to the Before/After surveys were included in the study, with 2,969 NSs for the Before knowledge questionnaire and 2,095 for the After



**Fig. 3** Percentage of student satisfaction with teaching techniques used (N=2,172)

**Table 2** Knowledge test scores and knowledge levels

Test		Beginning of semester average score (sd)	End of semester average score (sd)	Points score progression	p value
Test WHO	HH (score out of 25)	17.10 (1.28)	18.0 (1.21)	+1.78	<b>p&lt;0.001</b>
Test Tavalacci and al.	HAI (score out of 5)	2.68 (0.35)	2.58 (0.23)	-0.10	p=0.89
	SP (score out of 12)	11.20 (0.29)	11.50 (0.24)	+0.31	<b>p&lt;0.001</b>
	HH (score out of 8)	4.80 (0.33)	4.94 (0.47)	+0.14	<b>p=0.047</b>
	Total (score out of 25)	18.70 (0.70)	19.00 (0.64)	+0.30	<b>p=0.005</b>
2 tests combined	Total (score out of 50)	35.80 (1.74)	37.90 (1.75)	+2.10	<b>p&lt;0.001</b>

sd = standard deviation; HH = Hand Hygiene; HAI = healthcare-associated infections; SP = Standard Precautions

**Table 3** Progression of total knowledge test score with respect to teaching techniques

Teaching technique	Group using this technique	Number	Points score progression (sd)	p value
Synchronous lesson	Non	2	+1.83 (0.34)	p=0.778
	Oui	36	+1.68 (1.47)	
Asynchronous lesson	Non	15	+2.18 (1.42)	p=0.830
	Oui	23	+2.07 (1.48)	
Flipped class	Non	20	+2.23 (1.39)	p=0.596
	Oui	18	+1.98 (1.51)	
Non procedural simulation	Non	32	+2.18 (1.41)	p=0.517
	Oui	6	+1.76 (1.65)	
Quiz	Non	6	+1.65 (1.68)	p=0.395
	Oui	32	+2.20 (1.40)	
Case studies	Non	8	+2.05 (1.15)	p=0.895
	Oui	30	+2.13 (1.52)	
Serious game	Non	25	+1.84 (1.44)	p=0.097
	Oui	13	+2.65 (1.32)	
Mind mapping	Non	27	+2.11 (1.46)	p=0.974
	Oui	11	+2.13 (1.43)	
Audit	Non	31	+2.64 (1.38)	<b>p=0.050</b>
	Oui	7	+1.16 (1.38)	

sd = standard deviation

questionnaire. The mean score of the NTIs in this cohort was 35.8 ([35.3–36.3] sd = 1.74) for the initial knowledge questionnaire and 37.9 ([37.4–38.4] sd = 1.75) for the final questionnaire (Table 2). The total score improved by +2.1 points (NTI school-paired nonparametric Student's t = 7.33; Wilcoxon's test W = 46; p < 0.001). The level of knowledge was moderate at the beginning of the semester, then good at the end. The NAD increased the odds of having good knowledge by 157 times and moderate knowledge by 90 times on the questionnaire. Subgroup analysis of the same 1,825 students was carried out by paired tests. The same results were observed (data not shown).

Point progression was measured with respect to each teaching technique, and the influence of pedagogy on this progression was examined (Table 3). Only practice auditing improved the knowledge of the NSs (Student's t = 2.03; p = 0.050).

### Discussion

The NSs' knowledge of IPC at the beginning of their training was heterogeneous and moderate. By the end of the 1st semester of training, the IPC knowledge level of

the nursing students had improved slightly but significantly. NSs who had obtained an NAD diploma before starting their nursing education performed better than non NAD diploma. Of the different teaching techniques used, only practice auditing improved the knowledge of the NSs.

Our study showed that SP was acquired at the beginning of training. HH knowledge was good, but the use of hydro-alcoholic products still needed improvement. Training improved knowledge overall, in line with the findings of Carter et al. [13]. However, overall progress was poor, and the training did not improve basic knowledge of HAIs, consistent with the finding of Kra et al. [14]. These are important concepts for understanding infectious processes, and enable the NSs to understand IPC measurements. IPC education should not be confined to a single module or semester. Instead, core concepts such as hand hygiene, standard precautions, and environmental hygiene should be vertically integrated across the curriculum to reinforce learning, adapt to evolving student experience, and ensure long-term retention.

IPC teaching is a teaching unit involving 3 actors: the NTI, the university and the internship. The role of each in enabling NSs to acquire knowledge and then skills in IPC needs to be clarified. Are university courses suitable for NSs, considering that e-learning is less appreciated by NSs? Nurses supervise NSs on placement, yet the literature shows that professionals' knowledge of IPC is moderate to good, depending on the country and the study [15, 16]. Schneider et al. found that beginners' adherence improved under the supervision of adherent role models [17]. Therefore, the quality of supervision of NSs trainees is likely to have an impact on the acquisition of IPC skills. The questionnaire assessed the IPC knowledge of NSs, but was unable to assess SP compliance. We only tested the first level of Bloom's taxonomy classification of skill acquisition levels. There is a difference between the acquisition of knowledge and skills. This is an initial assessment of knowledge, which needs to be supplemented by an assessment of compliance and the acquisition of IPC skills.

What's more, students with an NAD diploma had better results in the IPC module from the beginning of their training, and after the courses the other NSs did not catch up. Some establishments offer NADs with a wide range of professional experience, with the agreement of their employer, benefit from an exemption from IPC teaching in nursing education, with a pathway that allows them to become nurses after only two years of training [18]. Most researchers have reported that students tend to modify their HH according to the practices they observe on the wards, in an effort to integrate into a team [19, 20]. To improve and maintain students' adherence to HH procedures, education during clinical placements needs to

be emphasized, which requires increased collaboration between placement tutors, the university and healthcare institutions [20]. It is essential to engage clinical mentors and role models in reinforcing IPC practices during placements. Educators should coordinate with practice settings to ensure consistent messages and behaviors are conveyed, avoiding contradictions between classroom teaching and clinical reality.

This study showed that the only way to improve knowledge and appropriation was for the NSs to carry out IPC audits with an evaluation grid of typical situations. The trainers were more interested in using practical exercises or games, such as educational games and simulations. It should be noted that our study did not show that serious games improved IPC knowledge in our sample, in contrast to a study conducted in Cyprus, which showed that games improved IPC knowledge [21]. A review of the literature has shown that the use of educational games in nursing education appears to be useful, but needs to be confirmed [22]. Similarly, with regard to simulation and virtual reality, we have not shown that these techniques are more effective, but a review of the literature has shown the value of these methods for improving IPC levels [23]. In light of the findings on teaching methods, the most promising avenue is to development of auditing case studies for NSs. This pedagogical technique, which is underused in IPC, has been shown to be effective in improving NS compliance with HH [24]. We suggest that audits could be carried out in the 3rd year of training as part of the "Quality of care, evaluation of practices" teaching unit. This would reinforce knowledge of IPC and enable concrete application of the quality approach and evaluation of professional practices. Furthermore, integrating audits into nursing curricula could offer valuable guidance for educators. Trainers would also like to have at their disposal simulation and room for error scenarios, as well as pedagogical games, as these teaching techniques are particularly appreciated by NSs. Simulation-based teaching, including hands-on practice and real-life scenarios, can help bridge the gap between theoretical knowledge and clinical application. This approach is particularly effective in teaching hand hygiene protocols, PPE usage.

There was substantial heterogeneity in the structure and delivery of IPC education across institutes, including differences in teaching hours, trainer qualifications, and local infection control policies. These contextual variations may have influenced the observed outcomes and limit the ability to draw standardized conclusions.

The MCQ type and the final scoring we have used for these questions has been chosen so that our results can be compared with other studies [5]. The number of NS who completed the survey at the beginning and end of the semester was substantial in absolute terms, but not

all students in the Before group completed the After form, with only pair 1,825 NSs (49%) completing both surveys. Concerning students, 2 questionnaires containing outliers were excluded, as were 878 incomplete questionnaires at the beginning of the semester and 555 for the end-of-semester survey. Students did not complete the questionnaire and incomplete questionnaires did not enable the 50-point score on the knowledge test to be obtained for the survey.” However, the profile of the Before and After cohorts was very similar. Participation in the survey declined towards the end of the semester, which may be explained by student and institutional factors. In the case of the NSs, we can hypothesize that these factors included varying personal motivation, stress over the upcoming end-of-semester exams and drop-outs. In 2021, 10% of students had dropped out of their first year of nursing training, compared to three times less in 2011 (3%). The dropout rate in the second and third years remains equally high: 7% in the second year and 4% in the third year in 2021 [25]. In terms of institutional factors, the inability to contact NSs directly via their official e-mail and only through their management, may have had an impact on their participation. It is likely that the NTIs who participated in the study were the most aware of, motivated by and invested in IPC training. The survey of trainers was conducted using a self-administered questionnaire, which may not accurately reflect the reality on the field, but rather the hoped-for or fantasized reality. The knowledge questionnaires used are those available in the French version. There may therefore be differences due to translation with others studies that used the English version. Furthermore, the didactic quality of the MCQs can be pointed, as their validation did not test before. Similarly, the Before/After knowledge assessment for NSs may not always have been organized under strict, supervised examination conditions, as it was left to the discretion of the trainers, which may have led to distortions and self-help in the answers. The same process for contacting the heads of all French nursing schools was used on both occasions, and as all the French schools were targeted, we can only guarantee the high number of responses from both students and school heads. However, we cannot respond to the doubts raised on the cohort. In both the initial and final feedback, we did not find any sub-groups with fundamentally different feedback. Finally, the descriptive graphs of our results did not point us in the direction of Simpson’s paradox. Finally, having analysed these questionnaires by combining them with a pairing at school level is also a limitation of our approach.

A large number of trainers participated in this study, and were asked about many of the teaching techniques they used. A precise definition of each teaching technique was given, but this wealth of information may not

have been fully understood. As teaching techniques are systematically combined, it is difficult to conclude from individual assessments that audits alone have added value. This study was carried out in France only, so extrapolation of the results to other countries is limited. The assessment was limited to factual knowledge and did not measure higher-order cognitive skills or actual application of knowledge in clinical contexts. Future studies should include assessments of practical competencies and clinical reasoning in IPC. This study focused solely on knowledge acquisition and did not assess behavioral change, SP compliance, or the downstream impact on infection rates. Integrating behavioral audits or observational data would enhance understanding of educational effectiveness.

The timing of the post-training assessment, occurring shortly after the IPC training, likely captured immediate knowledge gains. It remains unclear whether these improvements are retained over the long term, underscoring the need for longitudinal follow-up studies.

## Conclusion

The NSs’ knowledge of IPC at the beginning of their training was heterogeneous and moderate. Current IPC training in initial nursing education in France contributes to improving the knowledge of nursing staff. However, given the number of hours of training, the variety of teaching techniques used and the amount of time spent by the trainers, there is little progress in knowledge. It seems necessary to provide trainers and NSs with ready-to-use tools, such as a summary sheet of the essentials, simulation scenarios, error rooms, audit protocols and serious games, and to evaluate their effectiveness. It would also be interesting to carry out a study on the contribution of the course in terms of knowledge and best practice, as well as an assessment of IPC knowledge at the end of the 3-year training course.

For a future study, we suggest assessing knowledge at the start of training as well as at the end of training, in order to verify whether knowledge has been acquired on a lasting basis, and to complement this study with an assessment of practices.

## Abbreviations

HAIs	Healthcare Associated Infections
SP	Standard Precautions
HH	Hand Hygiene
WHO	World Health Organization
NS	Nursing Student
IPC	Infection Prevention and Control
NTI	Nursing Training Institute
NAD	Nursing Auxiliary Diploma
Sd	Standard deviation

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12912-025-03316-1>.

Supplementary Material 1

Supplementary Material 2

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Not available.

## Author contributions

SBM and CL conceptualized and designed the study. Statistical analysis was carried out by PG. SBM, PG and CL analyzed and interpreted the data. SBM and PG drafted the manuscript. SBM, PG and CL approved the final version of the manuscript. This study was conducted in compliance with the ethical principles set out in the World Medical Association's Declaration of Helsinki (latest revision 2013). All participants were informed in a clear and comprehensible manner of the objectives, modalities and purposes of the research, and their informed consent was obtained prior to their inclusion in the study. No personal data allowing the identification of participants is disclosed in this manuscript, in accordance with the respect for confidentiality and the protection of personal data. No conflicts of interest have been identified among the authors.

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## Data availability

Data are available on a reasonable request.

## Declarations

### Ethics approval and consent to participate

Research was conducted in compliance with the Helsinki Declaration. The clinical research direction of Grenoble Alps University Hospital in France classified the survey as a RNIPH (Research Not Involving the Human Person) according to the French research methodology (MR-004). Only informed consent to participate was obtained from all of the participants.

### Consent for publication

Not available.

### Competing interests

The authors declare no competing interests.

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