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RESEARCH ARTICLE

Use of a clinical decision support system to support pharmacy students' management of minor illnesses: A single-arm quasi-experimental pre–post study

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Abstract

Background: Pharmacists are expected to manage minor illnesses using clinical judgment and evidence-based practices. Clinical decision support systems may assist pharmacy students in developing pharmaceutical prescribing skills. The objective is to assess changes in pharmacy students' prescribing competence before and after using SEMIOPHARM/1, an educational clinical decision support system for minor illnesses. **Methods:** This single-arm quasi-experimental pre–post study was conducted between August and September 2021 with undergraduate pharmacy students at the Federal University of Sergipe, Brazil. Students completed simulated upper respiratory tract cases before and after software-supported training. Prescriptions were evaluated using a six-item competence rubric. As outcomes were ordinal, paired comparisons used the Wilcoxon signed-rank test with Bonferroni adjustment. **Results:** Of 36 students completing baseline assessment, 18 completed both phases and were included in paired analyses. Post-intervention improvements were observed in identifying therapeutic needs, selecting treatment, reporting presentation route, dose, route, and frequency, and recommending non-pharmacological measures. "Duration of treatment" showed no significant improvement after adjustment for multiple comparisons. **Conclusion:** Use of SEMIOPHARM/1 was associated with improved prescribing competence in selected domains; however, findings should be interpreted as preliminary due to the single-arm design, small paired sample, and absence of a control group.

Introduction

Minor illnesses, also referred to as self-limiting conditions or minor ailments, are generally non-serious health problems that can often be managed without medical consultation (Makhlouf *et al.,* 2021; Yusuff *et al.,* 2021). Community pharmacists are frequently the first point of contact for patients seeking advice for these conditions and may contribute to safe self-care through patient assessment, counselling, and appropriate referral when warning signs are present (Nakhla & Shiamptanis, 2021; You *et al.,* 2011). In this context, pharmacists may recommend over-the-counter medicines and non-pharmacological measures to support symptom relief and safe self-management (Richardson *et al.,* 2018; Saab *et al.,* 2018). Although access to over-the-counter medicines may facilitate timely symptom relief, inappropriate self-medication, medication overuse, and incomplete assessment of warning signs may compromise patient safety (Albarrak *et al.,* 2014; White *et al.,* 2018).

Pharmacists are increasingly expected to contribute to patient assessment, minor illness management, and, in some settings, prescribing activities through supplementary or collaborative models (Vale, 2018; Nakhla & Shiamptanis, 2021; Ramos *et al.,* 2022). In Brazil, pharmaceutical prescribing is regulated by the Federal Council of Pharmacy, reinforcing the

professional responsibility of pharmacists in patient assessment, therapeutic decision-making, and safe prescription practices (Conselho Federal de Farmácia [CFF], 2013, 2016). These expanding roles reinforce the need for pharmacy graduates to develop clinical reasoning, patient assessment, therapeutic decision-making, communication, and pharmaceutical prescribing skills (Richardson *et al*., 2018; Sousa *et al*., 2023). Pharmacy education should therefore provide structured opportunities for students to integrate pharmacological knowledge with patient-centred decision-making and safe prescription construction (Mesquita *et al*., 2015; Mertens *et al*., 2024).

Digital technologies, virtual simulations, mobile learning, and clinical decision support systems have been increasingly explored in health professions education (DiVall *et al*., 2013; Briz-Ponce *et al*., 2016;). In pharmacy education, virtual simulations and technology-supported learning have been used to support self-care counselling, medication review, dispensing, and clinical decision-making activities (Johnson *et al*., 2021; Mazan *et al*., 2022; Rude *et al*., 2023). Recent studies also suggest that structured digital learning environments may support clinical decision-making and competency development among pharmacy students (Mertens *et al*., 2024; Al-Diery *et al*., 2024). However, the integration of structured clinical decision support systems into undergraduate pharmacy education remains limited, particularly for the management of minor illnesses and the construction of pharmaceutical prescriptions (Mikhael *et al*., 2022; Dabidian *et al*., 2024).

To address this educational gap, SEMIOPHARM/1 was developed as an educational clinical decision support system designed to support pharmacy students in managing minor illnesses through structured clinical algorithms. The software guides the clinical interview, supports the identification of warning signs and therapeutic options, and assists students in structuring pharmaceutical prescriptions. This study aimed to assess changes in undergraduate pharmacy students' prescription competence before and after using SEMIOPHARM/1, focusing on clinical decision-making and prescription completeness in simulated minor-illness cases.

Methods

Study design

This was a single-arm quasi-experimental pre–post educational study designed to assess pharmacy students' prescription performance before and after using SEMIOPHARM/1, a clinical decision support system developed to support the management of minor illnesses. As the study did not include a control group or randomisation, it was intended to explore changes in students' performance over time rather than to establish a causal effect of the software. Setting and Participants

The study was conducted between August and September 2021 in the Bachelor's Degree in Pharmacy programme at the Federal University of Sergipe, Brazil. It was implemented during an elective course on pharmaceutical semiology. Because the course was offered as an elective component, students from different years of the pharmacy programme could enrol according to their academic trajectory, availability, and interest in the topic. Therefore, students from the first to the fifth year were eligible to participate. Participants may consequently have differed in their previous exposure to pharmaceutical care, clinical pharmacy, and prescription-related content, and this heterogeneity was considered when interpreting the findings.

A total of 36 students completed the baseline questionnaire and pre-intervention assessment. Of these, 18 completed both the pre- and post-intervention phases and were included in the paired prescription competence analysis. The remaining 18 students did not complete the post-intervention phase. Because the study was conducted within an elective course, non-completion of the second phase may have reflected several factors, including absence from the class session, discontinuation of the elective course, scheduling constraints, or reluctance to complete a second evaluative activity. Therefore, non-completion was not interpreted exclusively as withdrawal from the study.

Baseline questionnaire data were available for all 36 students. Students who completed both phases were compared descriptively with those who did not complete the post-intervention phase using available baseline demographic, educational, and self-perceived preparedness variables. However, the paired pre–post prescription competence analysis was restricted to the 18 students who completed both phases.

No a priori sample size calculation was performed. The sample size for the paired analysis was determined by the number of eligible students who completed both study phases; therefore, the analysis should be considered exploratory.

Description of SEMIOPHARM/1

SEMIOPHARM/1 is an educational clinical decision support system designed to support pharmacy

students in the structured assessment and management of minor illnesses and in the development of pharmaceutical prescribing competencies. The system guides students during simulated clinical cases by supporting patient assessment, identification of health needs, recognition of warning signs, selection of pharmacological and non-pharmacological interventions, and preparation of pharmaceutical prescriptions.

The development of SEMIOPHARM/1 was preceded by a literature search to identify clinical decision support systems used in pharmacy education to manage minor signs and symptoms. Searches were conducted in PubMed, Embase, Cochrane, LILACS, Scopus, and Web of Science using descriptors related to software, clinical decision support systems, mobile applications, pharmacists, pharmacy students, pharmacy education, nonprescription drugs, self-care, and self-medication.

The system was also informed by a previous decision support system developed to assist community pharmacists in clinical decision-making related to responsible self-medication and the management of minor ailments in community pharmacy settings (da Rocha *et al*., 2016). In addition, its educational and simulation-based structure was informed by previous virtual patient software developed to support pharmaceutical care education and the management of medication-related problems in simulated practice environments (Menendez *et al*., 2015).

SEMIOPHARM/1 was developed by a multidisciplinary team comprising production engineering students, professors with expertise in clinical pharmacy, pharmaceutical semiology, pharmaceutical prescription, and software development, and a pharmaceutical researcher. The development process involved 41 face-to-face and virtual meetings between 2018 and 2021. These meetings addressed the software structure, programming language, clinical reasoning steps, collection and analysis of patient information, identification of health needs and warning signs, referral criteria, selection of appropriate interventions, preparation of the care plan, documentation of the health care process, and final functional adjustments.

The system was implemented using JavaScript with React, allowing access through web browsers and mobile devices such as tablets and smartphones. This structure enabled the development of an interactive interface, the incorporation of updated clinical flowcharts, the management of more than one symptom simultaneously, and the updating of drug-related information when necessary.

The clinical algorithms incorporated evidence-based information for minor ailments, including cough, sore throat, cold, flu, constipation, diarrhoea, heartburn, and dyspepsia. The pharmacological content was updated in accordance with current clinical practice protocols and the list of over-the-counter medicines regulated by the Brazilian National Health Surveillance Agency through Normative Instruction No. 86, dated March 12, 2021 (Agência Nacional de Vigilância Sanitária [ANVISA], 2021). Additional drug-related information was checked using sources such as UpToDate, Micromedex, and Medscape.

During use, students select the patient's main complaint from the home screen and may include more than one minor symptom. The system then guides students through structured history-taking questions related to the selected symptoms, patient characteristics, comorbidities, symptom duration, previous medication use, and warning signs. The decision-tree algorithm uses the patient's responses to support clinical reasoning and indicate whether the case may be managed as a minor illness or whether referral to another health professional is required.

The outputs generated by SEMIOPHARM/1 include guidance on possible self-limiting conditions, referral alerts when warning signs are present, pharmacological management options when appropriate, non-pharmacological recommendations, and a structured pharmaceutical prescription. The prescription screen includes patient identification, treatment recommendations, drug or formulation name when applicable, pharmaceutical form, route of administration, dose, frequency, duration of treatment, additional instructions, and non-pharmacological measures. The prescription can be reviewed, edited, saved, and printed by the student.

In this study, SEMIOPHARM/1 was used exclusively as an educational tool in simulated clinical cases. It was not intended to replace clinical judgement, professional supervision, or individualised patient assessment. Therefore, its outputs should be interpreted as decision-support guidance rather than definitive clinical decisions.SEMIOPHARM/1 had not undergone formal external validation, algorithm validation, or usability testing with a validated usability instrument before the present educational application. This is acknowledged as a limitation and should be addressed in future studies.

Post-use perceived usability and acceptability assessment

After completing the post-intervention simulated case, students answered a post-use perceived usability and acceptability questionnaire adapted from instruments previously used to evaluate educational virtual patient software in pharmaceutical care education. The

questionnaire was informed by items reported in the evaluation of the PharmaVP Software and by instruments described by Hussein and Kawahara (2006) and Zary *et al*. (2006).

The items assessed students' perceptions of the educational approach, organisation of therapeutic reasoning, confidence in applying therapeutic information, operational functioning of the technology, time required to complete the prescription, similarity to real practice, perceived challenge, learning difficulties, and perceived potential for learning. Responses were recorded using a five-point Likert scale ranging from "strongly disagree" to "strongly agree".

In the present study, this questionnaire was used descriptively to assess students' perceived usability, acceptability, and educational experience with SEMIOPHARM/1. It was not intended to constitute formal external validation of the software, algorithm validation, or psychometric validation of the prescription competence rubric.

Prescription competence assessment

Students' prescriptions were assessed using a six-item pharmaceutical prescription competence rubric adapted for the simulated clinical case. The rubric was developed by the research team by mapping the expected components of pharmaceutical management for minor upper respiratory symptoms onto essential elements of pharmaceutical prescribing and patient-centred pharmaceutical services. These elements included identification of the patient's needs, definition of the clinical problem, selection of appropriate pharmacological or non-pharmacological treatment, completeness of prescription information, non-pharmacological counselling, and guidance for problem resolution or referral when necessary.

The rubric assessed: (1) identification of the patient's needs and definition of the clinical problem; (2) indication of appropriate pharmacological or non-pharmacological treatment; (3) completeness of presentation, dose, route, and frequency; (4) duration of treatment; (5) non-pharmacological recommendations; and (6) whether the prescription solved or guided the resolution of the patient's problem.

Each item was scored from 0 to 4, where 0 = not performed, 1 = performed inadequately, 2 = performed incompletely, 3 = performed well, and 4 = performed very well. The adapted rubric was used as an educational assessment tool in this study. It was not subjected to formal psychometric validation, external content validation, or reliability testing in the present sample.

For the simulated case, the expected clinical management involved recognising a self-limiting upper respiratory condition compatible with the common cold, without immediate warning signs; recommending hydration, rest, avoidance of cold air exposure, and symptomatic relief; considering over-the-counter medicines only when compatible with the reported symptoms; providing clear information on presentation, dose, route, frequency, and duration when a medicine was recommended; and advising referral or medical evaluation if warning signs appeared or symptoms worsened.

Prescription scoring was performed by one trained evaluator using the structured rubric. Because the evaluator was not blinded to the pre- or post-intervention phase and inter-rater reliability was not assessed, potential scoring subjectivity is recognised as a limitation.

Statistical analysis

Because the prescription competence items were ordinal scores, descriptive results are presented as medians and interquartile ranges. Means and standard deviations are also reported as complementary descriptive measures. Paired pre–post comparisons were performed using the Wilcoxon signed-rank test. To account for multiple comparisons across the six competence items, Bonferroni-adjusted p-values were calculated. Effect sizes were estimated using r, calculated from the Wilcoxon test statistic. Statistical significance was interpreted using adjusted p-values.

For the duration-of-treatment item, all students scored zero at baseline, resulting in a degenerate pre-intervention distribution. Therefore, the Wilcoxon result for this item was interpreted with caution and not considered robust evidence of change in this domain.

Results

Participant characteristics

Of the 36 students who completed the baseline questionnaire and pre-intervention assessment, 18 completed both study phases and were included in the paired prescription competence analysis. The remaining 18 students did not complete the post-intervention phase. Baseline characteristics of students who completed both phases and those who did not complete the post-intervention phase are presented descriptively in Table I.

Table I: Baseline characteristics of students according to completion of the post-intervention phase

Variable	Category/response	Completed both phases (n = 18)	Did not complete post-intervention phase (n = 18)	Total baseline sample (n = 36)
Sex	Female	15 (83.3)	11 (61.1)	26 (72.2)
	Male	3 (16.7)	7 (38.9)	10 (27.8)
Age, years	Mean (SD)	21.4 (2.2)	20.7 (1.9)	21.0 (2.0)
	Minimum-maximum	19-28	19-26	19-28
Age group, years	19-24	17 (94.4)	17 (94.4)	34 (94.4)
	25-29	1 (5.6)	1 (5.6)	2 (5.6)
Academic year in the pharmacy programme	1st year	1 (5.6)	11 (61.1)	12 (33.3)
	2nd year	8 (44.4)	5 (27.8)	13 (36.1)
	3rd year	5 (27.8)	1 (5.6)	6 (16.7)
	4th year	3 (16.7)	0 (0.0)	3 (8.3)
	5th year or later	1 (5.6)	1 (5.6)	2 (5.6)
Previous coursework covering pharmaceutical care	Yes	16 (88.9)	7 (38.9)	23 (63.9)
	No	2 (11.1)	11 (61.1)	13 (36.1)
Discipline previously completed, if applicable	Community Pharmaceutical Teaching Practice (PTPC/PEFC/PEC)	13 (72.2)	6 (33.3)	19 (52.8)
	Clinical Pharmacy and PTPC/PEFC	3 (16.7)	1 (5.6)	4 (11.1)
	No previous coursework	2 (11.1)	11 (61.1)	13 (36.1)
Knowledge of the concept of self-limiting health problems	Yes	16 (88.9)	14 (77.8)	30 (83.3)
	No	2 (11.1)	4 (22.2)	6 (16.7)
Self-perceived ability to manage common conditions such as cold/flu, cough, diarrhoea, or allergic rhinitis	Strongly agree	1 (5.6)	3 (16.7)	4 (11.1)
	Agree	6 (33.3)	5 (27.8)	11 (30.6)
	Neither agree nor disagree	9 (50.0)	8 (44.4)	17 (47.2)
	Disagree	0 (0.0)	2 (11.1)	2 (5.6)
	Strongly disagree	2 (11.1)	0 (0.0)	2 (5.6)
Perceived contribution of the teaching-learning strategy used at UFS to learning about self-limiting health problems	Strongly agree	4 (22.2)	6 (33.3)	10 (27.8)
	Agree	11 (61.1)	11 (61.1)	22 (61.1)
	Neither agree nor disagree	3 (16.7)	1 (5.6)	4 (11.1)
	Disagree	0 (0.0)	0 (0.0)	0 (0.0)
	Strongly disagree	0 (0.0)	0 (0.0)	0 (0.0)
Perceived contribution of digital technologies to clinical skills in minor illness management	Strongly agree	10 (55.6)	7 (38.9)	17 (47.2)
	Agree	8 (44.4)	10 (55.6)	18 (50.0)
	Neither agree nor disagree	0 (0.0)	1 (5.6)	1 (2.8)
	Disagree	0 (0.0)	0 (0.0)	0 (0.0)
	Strongly disagree	0 (0.0)	0 (0.0)	0 (0.0)
Expected knowledge by the end of the pharmacy programme regarding minor illness management and pharmaceutical prescription	Strongly agree	9 (50.0)	9 (50.0)	18 (50.0)
	Agree	9 (50.0)	8 (44.4)	17 (47.2)
	Neither agree nor disagree	0 (0.0)	1 (5.6)	1 (2.8)
	Disagree	0 (0.0)	0 (0.0)	0 (0.0)
	Strongly disagree	0 (0.0)	0 (0.0)	0 (0.0)
Expected ability by the end of the pharmacy programme regarding minor illness management and pharmaceutical prescription	Strongly agree	6 (33.3)	7 (38.9)	13 (36.1)
	Agree	11 (61.1)	9 (50.0)	20 (55.6)
	Neither agree nor disagree	1 (5.6)	2 (11.1)	3 (8.3)
	Disagree	0 (0.0)	0 (0.0)	0 (0.0)
	Strongly disagree	0 (0.0)	0 (0.0)	0 (0.0)

Note. Values are presented as n (%) unless otherwise indicated. Baseline questionnaire data were available for all 36 students who completed the pre-intervention assessment. The paired prescription competence analysis included only students who completed both the pre- and post-intervention phases. No inferential comparison was performed because the study was exploratory and not powered to compare completers and non-completers.

Descriptive comparison of baseline questionnaire data suggested that students who completed both phases may have differed from those who did not complete the post-intervention phase in some educational characteristics, particularly previous exposure to pharmaceutical care-related coursework, participation in Community Pharmaceutical Teaching Practice, and academic year in the pharmacy programme. These differences suggest that selection bias cannot be excluded and should be considered when interpreting the paired pre–post findings.

Among students included in the paired analysis, most were female (n = 15, 83.3%) and aged between 19 and 24 years (n = 17, 94.4%). Students were distributed across different years of the pharmacy programme, with the largest proportions enrolled in the second (n = 8, 44.4%) and third years (n = 5, 27.8%).

Most students included in the paired analysis had previously completed coursework covering pharmaceutical care (n = 16, 88.9%). Most also reported knowing the concept of self-limiting health problems (n = 16, 88.9%). However, only seven students (38.9%) agreed or strongly agreed that they felt able to manage common conditions such as cold/flu, cough, diarrhoea, or allergic rhinitis without support. All students included in the paired analysis agreed or strongly agreed that digital technologies, such as software, could contribute to the development of clinical skills related to minor illness management.

Table II shows the distribution of prescription competence scores before and after the use of SEMIOPHARM/1. Before the intervention, most students performed incompletely in identifying the patient's needs and defining the clinical problem, with 17 students (94.4%) scoring 2 and one student (5.6%) scoring 3. After the intervention, the distribution shifted towards higher scores: nine students (50.0%) scored 3, and one student (5.6%) scored 4.

Table II: Assessment of students' pharmaceutical prescriptions before and after using SEMIOPHARM/1

Competence item	Score 0 Pre n (%)	Score 0 Post n (%)	Score 1 Pre n (%)	Score 1 Post n (%)	Score 2 Pre n (%)	Score 2 Post n (%)	Score 3 Pre n (%)	Score 3 Post n (%)	Score 4 Pre n (%)	Score 4 Post n (%)
1. Identifies the patient's needs and clearly defines the problem	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	17 (94.4)	8 (44.4)	1 (5.6)	9 (50.0)	0 (0.0)	1 (5.6)
2. Correctly indicates treatment or drug name (appropriate selection)	3 (16.7)	0 (0.0)	11 (61.1)	0 (0.0)	4 (22.2)	8 (44.4)	0 (0.0)	4 (22.2)	0 (0.0)	6 (33.3)
3. Provides presentation, dose, route, and frequency	17 (94.4)	3 (16.7)	0 (0.0)	4 (22.2)	0 (0.0)	0 (0.0)	1 (5.6)	2 (11.1)	0 (0.0)	9 (50.0)
4. Provides duration of treatment	18 (100.0)	15 (83.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	3 (16.7)
5. Provides non-pharmacological treatment	14 (77.8)	3 (16.7)	1 (5.6)	0 (0.0)	1 (5.6)	0 (0.0)	2 (11.1)	3 (16.7)	0 (0.0)	12 (66.7)
I6. Solves or guides the resolution of the patient's problem	0 (0.0)	0 (0.0)	11 (61.1)	0 (0.0)	7 (38.9)	8 (44.4)	0 (0.0)	5 (27.8)	0 (0.0)	5 (27.8)

Note. Scores: 0 = did not perform; 1 = performed inadequately; 2 = performed incompletely; 3 = performed well; 4 = performed very well. Values are n (%), n = 18.

For treatment selection, no student scored 3 or 4 before the intervention. After using SEMIOPHARM/1, four students (22.2%) scored 3 and six students (33.3%) scored 4. For presentation, dose, route, and frequency, 17 students (94.4%) scored 0 before the intervention, whereas nine students (50.0%) scored 4 after the intervention. Duration of treatment remained the weakest domain: all students scored 0 before the intervention, and 15 students (83.3%) still scored 0 after the intervention.

Non-pharmacological recommendations increased substantially. Before the intervention, 14 students (77.8%) scored 0; after the intervention, 12 students (66.7%) scored 4. Similarly, the ability to solve or guide the resolution of the patient's problem shifted towards higher scores after SEMIOPHARM/1, with five students (27.8%) scoring 3 and five students (27.8%) scoring 4.

Table III presents the paired statistical comparisons. After Bonferroni adjustment, statistically significant increases were observed for identification of the clinical problem, treatment selection, presentation,

dose, route, and frequency, non-pharmacological recommendations, and resolution guidance. The duration-of-treatment item did not remain statistically significant after adjustment and should be interpreted cautiously because all baseline scores were zero.

Table III: Comparison of prescription competence scores before and after SEMIOPHARM/1

Competence item	Pre Median (IQR)	Post Median (IQR)	Pre Mean (SD)	Post Mean (SD)	Raw p	Bonferroni-adjusted p	Effect size r
1 — Identifies the patient's needs and clearly defines the problem	2.0 (2.0–2.0)	3.0 (2.0–3.0)	2.06 (0.24)	2.61 (0.61)	0.0039	0.0234	0.68
2 — Correctly indicates treatment or drug name (appropriate selection)	1.0 (1.0–1.0)	3.0 (2.0–4.0)	1.06 (0.64)	2.89 (0.90)	<0.001	0.0015	0.86
3 — Provides presentation, dose, route, and frequency	0.0 (0.0–0.0)	3.5 (1.0–4.0)	0.17 (0.71)	2.56 (1.69)	<0.001	0.0030	0.82
4 — Provides duration of treatment	0.0 (0.0–0.0)	0.0 (0.0–0.0)	0.00 (0.00)	0.67 (1.53)	0.0833	0.4996	0.41
5 — Provides non-pharmacological treatment	0.0 (0.0–0.0)	4.0 (3.0–4.0)	0.50 (1.04)	3.17 (1.50)	<0.001	0.0031	0.82
6 — Solves or guides the resolution of the patient's problem	1.0 (1.0–2.0)	3.0 (2.0–3.8)	1.39 (0.50)	2.83 (0.86)	<0.001	0.0016	0.86

Note. IQR = interquartile range; SD = standard deviation. Wilcoxon signed-rank tests were used for paired pre–post comparisons. Bonferroni correction was applied for six comparisons. Effect size r was calculated from the approximated z statistic divided by the square root of the number of non-zero paired differences. Because all students scored 0 at baseline for treatment duration, Item 4 should be interpreted cautiously.

Students' post-use perceptions of SEMIOPHARM/1

Table IV presents students' post-use perceptions of SEMIOPHARM/1. Overall, students reported favourable perceptions of the software as an educational tool. Most students agreed or strongly agreed that the method used with SEMIOPHARM/1 helped organise their reasoning and care plan, increased their confidence in applying therapeutic information, and functioned adequately during the resolution of the simulated case. Students also perceived the approach as closer to real practice than other teaching strategies.

Table IV: Students' post-use perceptions of SEMIOPHARM/1 (n = 18)

Item	Strongly agree n (%)	Agree n (%)	Neither agree nor disagree n (%)	Disagree n (%)	Strongly disagree n (%)
The teaching approach used with SEMIOPHARM/1 was different from other teaching approaches.	6 (33.3)	8 (44.4)	2 (11.1)	2 (11.1)	0 (0.0)
The method for analysing the case and establishing the care plan with SEMIOPHARM/1 helped me organise my reasoning.	8 (44.4)	8 (44.4)	2 (11.1)	0 (0.0)	0 (0.0)
SEMIOPHARM/1 helped me gain more confidence in my ability to apply therapeutic information.	8 (44.4)	9 (50.0)	1 (5.6)	0 (0.0)	0 (0.0)
The technology used in SEMIOPHARM/1 functioned adequately during the resolution of the clinical case.	6 (33.3)	9 (50.0)	3 (16.7)	0 (0.0)	0 (0.0)
The technology used in SEMIOPHARM/1 made me spend too much time completing the prescription.	3 (16.7)	1 (5.6)	4 (22.2)	7 (38.9)	3 (16.7)
The technology used in SEMIOPHARM/1 was closer to real practice than other teaching methods.	4 (22.2)	12 (66.7)	2 (11.1)	0 (0.0)	0 (0.0)
The approach used with SEMIOPHARM/1 could support better management of simulated minor illness cases.	6 (33.3)	9 (50.0)	3 (16.7)	0 (0.0)	0 (0.0)
Using SEMIOPHARM/1 was challenging for me.	2 (11.1)	4 (22.2)	2 (11.1)	10 (55.6)	0 (0.0)
I did not experience learning difficulties when using SEMIOPHARM/1.	3 (16.7)	8 (44.4)	5 (27.8)	2 (11.1)	0 (0.0)
I think I can learn using SEMIOPHARM/1.	9 (50.0)	6 (33.3)	3 (16.7)	0 (0.0)	0 (0.0)

Note. Values are presented as n (%). Items describe students' post-use perceptions of SEMIOPHARM/1 and should not be interpreted as formal usability validation, psychometric validation, or evidence of clinical patient outcomes.

Responses were more heterogeneous for items related to the time required to complete the prescription and whether the use of SEMIOPHARM/1 was challenging. These findings should be interpreted as descriptive indicators of perceived usability, acceptability, and educational experience rather than formal validation of the software.

Discussion

This single-arm quasi-experimental pre–post study found that the use of SEMIOPHARM/1 was associated with higher post-intervention scores in several domains of pharmaceutical prescription competence among undergraduate pharmacy students. The most pronounced changes were observed in treatment selection, reporting of presentation, dose, route, and frequency, non-pharmacological recommendations, and guidance for the resolution of the patient's problem. These findings suggest that a structured clinical decision support system may help students organise clinical reasoning and prescription elements when managing simulated minor illnesses. However, because this study did not include a control group, randomisation, or blinding, the observed changes should be interpreted as preliminary associations rather than evidence of a causal effect of SEMIOPHARM/1 alone.

Before using SEMIOPHARM/1, students showed limited ability to transform clinical reasoning into a structured pharmaceutical prescription. Although many students proposed anamnesis questions and recognised the need to investigate symptoms, most pre-intervention responses did not include complete treatment selection, dose, frequency, duration, or non-pharmacological recommendations. This gap between theoretical questioning and prescription construction is consistent with challenges described in pharmacy education, particularly the difficulty of translating knowledge into applied clinical decision-making and patient-centred care (Turney *et al*., 2009; Kaur, 2017; Mesquita *et al*., 2015). Recent evidence also reinforces the importance of structured teaching models to support clinical decision-making among pharmacists and pharmacy students (Mertens *et al*., 2024).

After using SEMIOPHARM/1, students' prescriptions became more structured. Complete reporting of presentation, dose, route, and frequency increased from 0.0% before the intervention to 50.0% after the intervention. Similarly, the proportion of students rated as "performed very well" for non-pharmacological recommendations increased from 0.0% to 66.7%. These results suggest that the software may have supported students in organising key elements of pharmaceutical prescribing, especially those that are frequently omitted when students rely only on prior knowledge. This is relevant because safe management of minor illnesses requires not only the choice of an appropriate medicine, when needed, but also clear instructions, non-pharmacological guidance, and recognition of situations requiring referral (Makhlouf *et al.,* 2021; Nakhla & Shiamptanis, 2021; Yusuff *et al.,* 2021).

The improvement observed in non-pharmacological recommendations is particularly important. Minor illnesses are often self-limiting and may be managed with hydration, rest, avoidance of triggering factors, symptomatic relief, and monitoring for warning signs (You *et al*., 2011; Richardson *et al*., 2018; Saab *et al*., 2018). In the simulated case used in this study, the patient reported upper respiratory symptoms, absence of severe warning signs, and worsening after exposure to cold air conditioning. Therefore, adequate management required a proportional approach, avoiding unnecessary pharmacological escalation and reinforcing self-care measures. The increase in non-pharmacological recommendations after SEMIOPHARM/1 suggests that algorithm-guided tools may help students consider broader patient care strategies rather than focusing exclusively on medicine selection.

The findings are consistent with evidence showing that digital tools, virtual patients, virtual simulations, and computer-based simulations can support learning and clinical reasoning in pharmacy education. A systematic review on virtual patient simulation in pharmacy education found that this approach may enhance knowledge and clinical decision-making skills (Beshir *et al.,* 2022). Another systematic review on virtual patients and computer-based simulation in experiential pharmacy education reported improvements in student knowledge, clinical reasoning, counselling skills, confidence, and engagement (Phanudulkitti *et al.,* 2023). Similarly, studies using virtual pharmacy platforms such as MyDispense have reported positive effects on students' self-care assessment, dispensing-related competencies, confidence, and learning experience (Johnson *et al.,* 2021; Mazan *et al.,* 2022; Rude *et al.,* 2023; Al-Diery *et al.,* 2024). These findings support the educational relevance of structured digital tools, although the specific contribution of SEMIOPHARM/1 requires further controlled evaluation.

SEMIOPHARM/1 differs from serious games and virtual dispensing simulations because it uses structured decision-tree algorithms to guide symptom assessment and prescription construction. This characteristic brings

it closer to clinical decision support systems used in pharmacy practice. Evidence from medication-related CDSS studies suggests that these systems may contribute to safer and more efficient medication-related decision-making, although their effects depend on the clinical context, implementation strategy, usability, and quality of the underlying algorithms (Shahmoradi *et al*., 2021; Dabidian *et al*., 2024). However, the present study did not directly compare SEMIOPHARM/1 with serious games, virtual patients, MyDispense, or other CDSS-based approaches. Therefore, no conclusion can be drawn regarding its superiority over other digital or simulation-based educational strategies.

Students' post-use perceptions also suggested favourable acceptance of SEMIOPHARM/1 as an educational tool. Most students agreed or strongly agreed that the system helped organise reasoning and the care plan, increased confidence in applying therapeutic information, functioned adequately during the simulated case, and resembled real practice. These findings are consistent with previous studies in which pharmacy students perceived virtual patient or simulation-based tools as useful for developing confidence, engagement, and clinical reasoning (Beshir *et al.,* 2022; Phanudulkitti *et al.,* 2023; Al-Diery *et al.,* 2024). Nevertheless, these findings should be interpreted as descriptive indicators of perceived usability and acceptability, not as formal validation of the software.

Despite higher post-intervention scores in most domains, duration of treatment remained poorly reported. All students scored zero for duration before the intervention, and most continued to omit this information after using the software. This finding is clinically relevant because treatment duration is an essential component of a complete pharmaceutical prescription and contributes to safe medicine use. The absence of improvement in this item may indicate that students require additional training specifically focused on prescription completeness, duration limits for over-the-counter medicines, and follow-up instructions. It may also indicate that the software interface or training session did not sufficiently emphasise duration of treatment. This issue should be addressed in future versions of SEMIOPHARM/1 and in future teaching activities.

The statistical interpretation of the duration-of-treatment item requires caution. Since all students scored zero at baseline, the pre-intervention distribution had zero variance. This degenerate distribution limits the interpretability of the Wilcoxon signed-rank test for this specific item. Moreover, after Bonferroni adjustment for multiple comparisons, duration of treatment did not remain statistically significant. For this reason, the result should not be interpreted as evidence of a meaningful improvement in this domain. Instead, it highlights a persistent educational weakness that should be addressed in future interventions.

A strength of this study was the use of paired pre–post prescription assessments based on simulated clinical cases and a structured six-item competence rubric. This allowed the evaluation of specific domains of pharmaceutical prescribing, including treatment selection, completeness of presentation, dose, route, and frequency, duration of treatment, non-pharmacological recommendations, and guidance for problem resolution. In addition, SEMIOPHARM/1 was implemented in a real educational context, which increases the practical relevance of the findings for pharmacy education.

However, several limitations must be considered. First, the study used a single-arm pre–post design without a control group. Therefore, the observed changes cannot be attributed exclusively to SEMIOPHARM/1. Practice effects, increased familiarity with the prescription format, the 30-day interval between assessments, differences between simulated cases, and the four-hour training session may also have contributed to post-intervention performance. Second, the sample included in the paired analysis was small, and no a priori sample size calculation was performed. Thus, this study should be considered exploratory and may have been underpowered for some outcomes.

Third, non-completion of the post-intervention phase was substantial. Although 36 students completed the baseline questionnaire and pre-intervention assessment, only 18 completed both phases and were included in the paired analysis. To address this issue, baseline questionnaire data were used to compare, descriptively, students who completed both phases with those who did not complete the post-intervention phase. This comparison, presented in Table 1, suggested possible differences in previous exposure to pharmaceutical care-related coursework, participation in Community Pharmaceutical Teaching Practice, and academic progression. Therefore, selection bias cannot be excluded.

Students who completed both phases may have been more available, more engaged with the elective course, or more familiar with pharmaceutical care content. However, the pre-intervention open-text responses also indicated that previous exposure did not necessarily translate into complete pharmaceutical prescription performance, as many students focused on anamnesis questions but omitted key prescription elements. Because reasons for non-completion were

not systematically recorded, non-completion should not be interpreted solely as withdrawal from the study. It may also have reflected absence from the elective course session, discontinuation of the elective course, scheduling constraints, or reluctance to complete a second evaluative activity.

Fourth, the prescription competence rubric was adapted specifically for the simulated clinical case and was used as an educational assessment tool. The six items were defined by mapping the expected pharmaceutical management of minor upper respiratory symptoms onto essential elements of pharmaceutical prescribing, including clinical problem identification, treatment selection, prescription completeness, duration, non-pharmacological counselling, and guidance for problem resolution. However, the rubric was not subjected to formal psychometric validation, external content validation, or reliability testing in the present sample. Because prescription scoring was performed by a single evaluator who was not blinded to the study phase, subjectivity and lack of inter-rater reliability should also be recognised as limitations.

Although students completed a post-use perception questionnaire addressing acceptability, perceived usefulness, operational functioning, learning experience, and perceived usability, SEMIOPHARM/1 has not yet undergone formal external validation, algorithm validation, or usability testing using a validated usability instrument. Therefore, future studies should include structured usability testing, independent assessment of the decision algorithms, and evaluation of the system in different educational and clinical contexts.

Finally, both simulated cases addressed upper respiratory symptoms. Therefore, the findings should not be generalised to all minor illnesses, other body systems, or other educational contexts. Minor ailments such as diarrhoea, dyspepsia, constipation, skin conditions, and allergic symptoms may require different decision pathways and different prescription competencies.

Future studies should evaluate SEMIOPHARM/1 using larger samples, multicentre designs, control groups, and randomised or controlled educational approaches. Further research should also assess its use across different minor illness categories, include independent evaluators and inter-rater reliability analysis, and investigate whether improvements are retained over time or transferred to real or high-fidelity clinical practice.

Overall, the results suggest that SEMIOPHARM/1 may be a useful adjunct to pharmacy education by supporting structured reasoning and prescription construction in simulated minor illness scenarios. Nevertheless, its role should be understood as complementary to, rather than a replacement for, clinical supervision, professional judgement, and broader active learning strategies.

Conclusion

The use of SEMIOPHARM/1 was associated with higher post-intervention scores in selected pharmaceutical prescription competence domains among undergraduate pharmacy students, particularly treatment selection, presentation, dose, route, frequency, non-pharmacological recommendations, and guidance for problem resolution. However, duration of treatment remained poorly reported by most students.

Because this was a single-arm quasi-experimental pre–post study with a small paired-analysis sample, substantial non-completion of the post-intervention phase, no control group, and simulated cases restricted to upper respiratory symptoms, the findings should be interpreted as preliminary. SEMIOPHARM/1 may be a useful adjunct to other teaching strategies for supporting pharmacy students in the structured management of selected minor illnesses. However, further controlled, multicentre studies are needed to evaluate its educational impact across different clinical conditions, minor illness categories, and educational settings.

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Ethical considerations

This study was approved by the Research Ethics Committee of the Federal University of Sergipe, Brazil (CAAE: 50985721.8.0000.5546). Written informed consent was obtained from all participants prior to their participation.

Conflict of interest

The authors declare no conflicts of interest.

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