



The effectiveness of an educational program in improving nurses knowledge of blood transfusion safety: a cross-sectional study

Mohammed Ibrahim Humadi^{1,*}, Yaseen Mohammed Mussa^{1,*}

¹University of Kirkuk. College of Nursing. Department of Adult Nursing, Kirkuk, Iraq.

*Corresponding authors:

Mohammed Ibrahim Humadi

University of Kirkuk. College of Nursing.
Department of Adult Nursing, Kirkuk, Iraq.
E-mail: nsrm24009@uokirkuk.edu.iq

Yaseen Mohammed Mussa

University of Kirkuk. College of Nursing.
Department of Adult Nursing, Kirkuk, Iraq.
E-mail: yassen_mussa@uokirkuk.edu.iq

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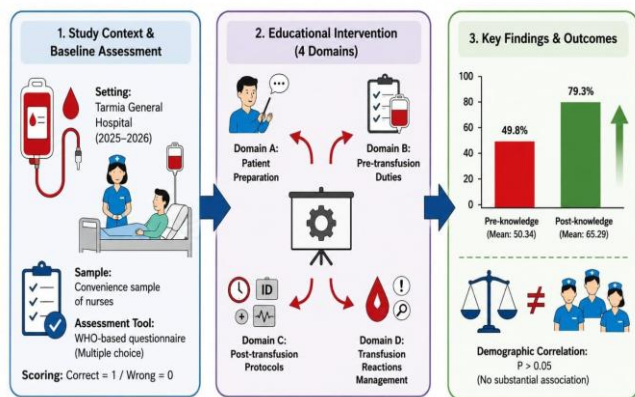
Abstract

Introduction: Blood transfusion is a safe and life-saving medical procedure in which blood or its components (red blood cells, platelets, and plasma) are transferred from a healthy donor into the patient's bloodstream using an intravenous catheter. This method is used to replace blood lost due to injuries or surgery, or to treat severe anemia and chronic diseases such as cancer and thalassemia. **Objective:** To assess the efficacy of a proposed educational program on nurses' knowledge of blood transfusion safety and identify the relationships between the demographic characteristics and their knowledge level. **Design:** A cross-sectional study was employed, utilizing a quantitative research methodology. The study was conducted between 19/11/2025 and 1/2/2026 to fulfill the predefined objectives. **Methods:** A convenience sample of nurses administering blood transfusions at Tarmia General Hospital was gathered. Data were gathered utilizing a structured questionnaire developed in accordance with WHO guidelines, encompassing demographic characteristics and associated variables, alongside knowledge pertaining to patient preparation, pre-transfusion responsibilities, post-transfusion protocols, and the management of blood transfusion reactions. The tool had multiple-choice questions

scored as (1) for correct replies and (0) for wrong responses. Reliability was evaluated with the Kuder-Richardson Formula-20 for internal consistency. Pre-Period = 50.3409, Post-Period = 65.2919. Data were evaluated employing descriptive statistics, including observed frequencies, percentages, mean scores, standard deviations, and relative sufficiency (RS%), alongside the Binomial test, One-sample Chi-Square test, One-Sample Kolmogorov-Smirnov test, McNemar test. **Results:** Knowledge increased from 49.8% to 79.3% in the post-test, and the average score also improved. Demographic characteristics and cognitive improvements were not substantially associated ($p > 0.05$). **Conclusion:** The introduction of an educational program has markedly enhanced nurses' knowledge across all examined areas, whereas minor correlations have been identified with nurses' sociodemographic factors and some associated variables.

Keywords: Educational program, Knowledge, Blood Transfusion safety.

Graphical Abstract



Source: Own authorship.

Introduction

A blood transfusion is a medical procedure in which a recipient receives blood or a blood component. The primary objective of blood transfusions is to restore blood lost due to surgery, trauma, or medical conditions that result in anemia or coagulation disorders [1-3]. Transfusion is recognized as one of the nine essential life-saving treatments designated by the WHO. Annually, about nine million people across 90 countries receive blood transfusions [4].

It is conducted on millions of individuals globally each year. The development of transfusion medicine in modern science is due to a combination of factors, such as the identification of blood types at the beginning of the 20th century, the resolution of anticoagulant problems, and technological advancements that led to improvements in sterilization methods and equipment [5]. Transfusions are widely performed in Saudi Arabia, first due to the need for medical care and the increasing incidence of traffic accidents [6].

According to the new recommendations, most severe transfusion complications occur within the initial 15 minutes of the transfusion. Therefore, close monitoring is recommended prior and during the first 15 minutes of the transfusion. The suggestions also emphasize close monitoring during sample collection and pre-transfusion testing to prevent any adverse responses [7]. Problems related to transfusion can be mitigated by monitoring the blood transfusion procedure [8]. Many countries have guidelines or standard rules that address important procedures for managing blood transfusions, such as screening blood donor for any infectious diseases, detecting the necessity for a transfusion, and determining blood type compatibility (ABO) [9].

The majority of mistakes in blood transfusions transpire in the wards, including the improper handling of blood bags at the patient's bedside and erroneous

patient identification [10]. Errors during transfusion can lead to significant morbidity or mortality rates among transfusion recipients. Human factors are the primary cause of mistakes during transfusion, which can be reduced by the development and execution of guidance programs and the continuous revision of blood transfusion protocols [11,12]. According to the Severe Hazards of Transfusion (SHOT) study, there were 13 transfusion-related deaths. Although these problems are preventable, they can be severe, shown ABO blood group incompatibility [13].

Monitoring transfusions is essential for minimizing transfusion mistakes. Numerous nations possess guidelines that encompass the primary elements of transfusion management, including blood group compatibility, donor screening for infectious illnesses, and the assessment of transfusion urgency [8]. Research and research aimed at formulating the most efficient strategies to guarantee patient safety and well-being are continually expanding due to the hazards linked to blood transfusions. Augmenting nurses' knowledge and awareness is crucial. Blood transfusion safety is a nursing technique that necessitates a thorough comprehension of the requisite measures to guarantee its safe and successful execution. Factors contributing to transfusion mistakes encompass insufficient understanding of compatibility testing, transfusion-related infections, delays in blood administration, and the recognition of delayed responses [1].

The safety of patients undergoing blood transfusions is fundamentally reliant on the security of the clinical transfusion procedure. This encompasses a series of sequential phases, including the description and selection of the blood component, collection of the patient's blood sample, identification of the appropriate patient, labeling of the corresponding sample, ensuring pre-compatibility testing, collection and transportation of blood bags within the healthcare institution, management of blood bags in the clinical environment, blood transfusion, and post-transfusion monitoring, which includes identification and management of transfusion-related adverse effects [7,14].

Safe blood transfusions need specialized and trained staff, given that transfusion is a difficult procedure. Proficiency is crucial throughout the entire process. Nurses assume a crucial and direct responsibility in the management of patients undergoing blood transfusions. The mitigation of blood transfusion-related risks to patients is predominantly contingent upon the nursing staff's expertise in blood transfusion procedures. The nursing staff's role is crucial for the efficient management of blood transfusions. A published study indicated that nurses'

knowledge and awareness of blood transfusion and safety were inadequate and below the necessary standard, thereby jeopardizing the safety of patients undergoing blood transfusions [15].

A 2019 report by the American Society of Registered Nurses highlights an urgent necessity for nurse education about blood transfusion dangers, contemporary safety requirements, nursing interventions, and decision-making processes. The assessment of nurses' competence and abilities should occur every day [16]. Nurses, via their professional responsibilities, have the opportunity to formulate policies and procedures, devise nursing interventions, and educate healthcare personnel to avert transfusion mistakes. Additional components are essential for training programs in nursing departments that educate nurses on minimizing transfusion hazards, contemporary safety protocols, and nursing interventions [17].

Recent clinical studies have confirmed that blood transfusion management remains prone to nursing procedural errors, underscoring the need for organized in-service educational interventions to guarantee that nursing complies with current international policies [18]. This research was performed in Tarmia General Hospital in Baghdad Governorate. This is the inaugural research in Baghdad Governorate assessing the influence of an educational program on nursing knowledge concerning blood transfusion.

Methods

The research employed a cross-sectional study to establish (one-group pre-test/post-test) design to establish predetermined objectives. To maintain high methodological standards, the STROBE checklist guidelines for cross-sectional research designs were followed throughout this study.

The study was conducted in accordance with the ethical principles and research policies of Kirkuk University/College of Nursing. Administrative approval was obtained before data collection began, in addition to written consent signed by the participants after the study's purpose was clearly explained. Participants were also assured that their information would remain confidential and be used solely for scientific research purposes.

A non-probability (targeted) convenience sampling method was used, targeting nurses working at the aforementioned hospital who perform blood transfusions. The sample size (according to the G Power NT program) for this study was 40 nurses working in different departments of the hospital who perform blood transfusions.

The research was carried out from November 19, 2025, to February 1, 2026. Inclusion criteria included: nurses employed at Tarmia General Hospital; nurses performing transfusions in diverse hospital departments; and nurses of both genders from all educational levels, working morning and evening shifts. The Exclusion criteria included: nurses on prolonged leave during the data collection, nurses who declined to participate in the study, and nurses working in employed departments. Data were collected utilizing a structured questionnaire constructed according to WHO principles, comprising: (7 items) for knowledge pertaining patient preparation, (14 items) for pre-transfusion responsibilities, (12 items) for post-transfusion procedures, and (16 items) related to blood transfusion reactions and their management.

The study instrument employed multiple-choice questions, with (1) awarded for right answers and (0) for incorrect answers. The reliability was evaluated using the Kuder–Richardson Formula-20 for internal consistency, which exceeded the threshold of 50.0%, with values recorded at (Pre Period = 50.3409 and Post Period = 65.2919). A score approaching 1 indicates greater test reliability. The instrument's content validation was confirmed by a team of 10 professionals to verify the questions were suitable, straightforward, and thorough. Data were evaluated utilizing descriptive statistics, including Observed Frequencies, Percentage, Mean Score (MS), Standard Deviation (SD), and Relative Sufficiency (RS%), as well as Binomial test, One-sample Chi-Square test, One-Sample Kolmogorov-Smirnov Test, McNemar test, and Analysis of Covariance (ANCOVA).

Results and Findings

Table 1 shows distribution of studied "Socio Demographical Characteristics and Some Related" variables (SDCv. & SRv.) of studied sample, including observed frequencies, and percentages, additionally, comparison's significant for testing the assumption validity regarding the random distribution for each variables assumed to identify the behavior of that variables in light of the studied sampling population, which indicated that restricted distribution are obtained in at least at $p < 0.05$, exceptional of gender had a similar distribution, rather than observed that 23 (57.0%) of female, and 17 (43.0%) of male, as well as, 28 (70.0%) of them their age less than thirty years old, 27 (67.5%) of them were married, 30 (75.0%) their academic achievement preparatory school and institute, 34 (85.0%) of them had experience less than ten years, 19 (47.5%) of them are from emergency and operating room work places, and 30 (75.0%) of

them had (1_5) training courses.

Table 1. Distribution of the studied Socio Demographical Characteristics and Some Related variables (SDCv. & SRv.) with comparisons of significant (N=40).

SDCv. & SRv.	Classes	No	%	C.S. (*) p-value
Gender	Male	17	43.0	P=0.429 (NS)
	Female	23	57.0	
Age Groups Per yrs.	20 _ 24	7	17.5	$\chi^2 = 16.200$ p=0.001 (HS)
	25 _ 29	21	52.5	
	30 _ 34	6	15.0	
	≤ 35	6	15.0	
	Mean ± SD	29.63 ± 8.13		
Marital Status	Single	11	27.5	K.S. = 0.342 p < 0.01 (HS)
	Married	27	67.5	
	Divorced	2	5.0	
Educational Level	Preparatory School	7	17.5	$\chi^2 = 10.850$ p=0.004 (HS)
	Institute of Nursing	23	57.5	
	College of Nursing	10	25.0	
Years of Experience (Per yrs.)	(1 _ 5) yrs.	17	42.5	$\chi^2 = 6.050$ p=0.049 (S)
	(6 _ 10) yrs.	17	42.5	
	≤ 11 yrs.	6	15.0	
Work Place	Emergency	11	27.5	K.S. = 0.253 At p < 0.05 (S)
	Dialysis	4	10	
	Private Suite	3	7.5	
	Internal Medicine Ward	3	7.5	
	Surgical Wards	3	7.5	
	Gynecology Ward	3	7.5	
	Respiratory Care Unit	2	5	
	Delivery room	3	7.5	
	Operating room	8	20	
Number of Training Courses	(1 _ 5)	30	75	K.S. = 0.417 At p < 0.01 (HS)
	(6 _ 10)	8	20	
	≤ 11	2	5	

(*) HS: Highly Sig. at p<0.01; S: Sig. at p<0.05; Testing based on One-Sample Chi-Square test, One-Sample Kolmogorov-Smirnov test, Binomial test, One-Sample Kolmogorov-Smirnov test. Source: Own authorship.

Table 2 shows a summary results of the knowledge main domains resulted through admixed form of studied knowledge' items which is exposed in (Appendix A), as well as an overall measurements scales of PGMS results at pre/post periods reveals that the estimated effects of the proposed educational program has raised the level of knowledge generally about 30%, where the estimates of initiated nurses'

knowledge and after implementation of a proposed program was accounted (49.8%, and 79.3%) respectively, and that indicates that there is approximately (20.0%) lack of knowledge grades lagging amongst the studied participants.

Table 2. Descriptive Statistics for the studied sample based on the Studied Domains, along with Pre/Post Periods, with comparisons significant.

Domains and Overall Assessment	Period	No.	Pre			
			GMS	SD	Ass.	C.S.
Nurses' Knowledge Regarding Patient Preparation	Pre	40	0.473	0.164	M	p = 0.000 (HS)
	Post	40	0.759	0.116	H	
Knowledge of sample about Pre-Transfusion role	Pre	40	0.475	0.140	M	p = 0.000 (HS)
	Post	40	0.756	0.126	H	
Knowledge of the Participants regarding procedure Post-Transfusion	Pre	40	0.559	0.148	M	p = 0.000 (HS)
	Post	40	0.838	0.117	H	
Knowledge of sample regarding Blood Transfusion reaction and management	Pre	40	0.486	0.190	M	p = 0.000 (HS)
	Post	40	0.818	0.165	H	
Overall Assessment	Pre	40	0.498	0.087	M	p = 0.000 (HS)
	Post	40	0.793	0.086	H	

(*) HS: Highly Sig. at P<0.01; Testing is based on Matched Paired t-test, where the procedural hypothesis (By applying the One-Sample Kolmogorov-Smirnov test) was proven that the data underlying follows the normal distribution function. Source: Own authorship.

Figure 1 illustrates distributions of the studied primary domains, as well as Overall Assessments, concerns percentile grand/global means of score – PGMS for the studied enhancing nurses' knowledge regarding blood transfusion safety.

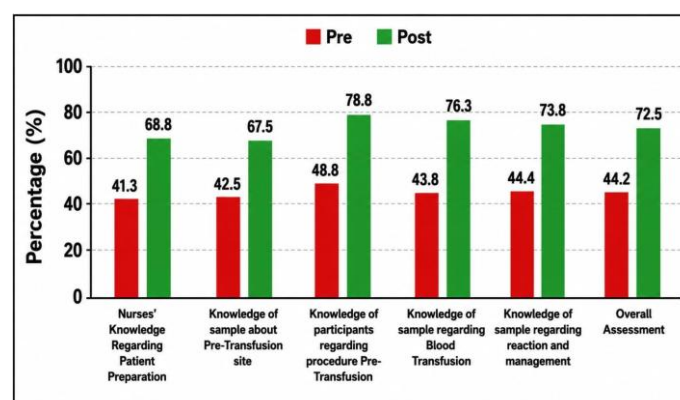


Figure 1. Cluster Bar Chart for the distribution of PGMS of the score of the studied nurse's knowledge concerning the studied Main Domain's assessments along Pre/Post Periods. Source: Own authorship.

Table 3 shows a summary of the studied responses of participants' nurses' knowledge regarding blood transfusion safety at pre- to post- periods by

applying a proposed program, distributed according to their Socio Demographical Characteristics and Some Related variables (SDCv. & SRv.). classes, such as "Percentile Global Mean of Score – PGMS, and Pooled Standard Deviation–PSD", which clearly indicates that the observed results of the most responses centered around the classification of demographic and some related variables before implementation of an educational program at the middle of the percentile range of assessment, while assessment score had risen after implementation of the educational program to higher range level of assessment.

Table 3. Summary statistics at studied Pre/Post Periods distributed according to their (SDCv. and SRv.) classes.

SDCv. & SRv.	Classes	Period	No.	PGMS	PSD
Gender	Male	Pre	17	50.18	8.80
		Post	17	81.02	8.10
	Female	Pre	23	49.58	8.79
		Post	23	77.97	8.94
Age Groups	20 _ 24	Pre	7	50.04	9.40
		Post	7	78.69	8.46
	25 _ 29	Pre	21	47.41	8.16
		Post	21	77.53	8.44
	30 _ 34	Pre	6	53.40	8.35
		Post	6	81.14	9.89
	≤ 35	Pre	6	54.49	8.98
		Post	6	84.14	8.08
Marital Status	Single	Pre	11	48.13	8.69
		Post	11	77.84	9.67
	Married	Pre	27	50.26	8.46
		Post	27	79.47	7.84
	Divorced	Pre	2	53.39	16.26
		Post	2	84.30	17.05
Level of Education	Nursing Preparatory School	Pre	7	51.85	4.92
		Post	7	77.15	8.09
	Nursing Institute	Pre	23	46.32	9.11
		Post	23	77.17	8.11
	College of Nursing	Pre	10	56.51	4.88
		Post	10	85.57	7.66
Work Place	Emergency	Pre	11	48.67	9.89
		Post	11	81.35	9.48
	Dialysis	Pre	4	50.74	7.04
		Post	4	84.78	3.46
	Private Suite	Pre	3	50.87	10.32
		Post	3	80.63	9.84
	Internal Medicine Ward	Pre	3	51.54	12.96
		Post	3	82.61	11.49
	Surgical Wards	Pre	3	40.85	8.93
		Post	3	68.73	5.63
	Gynecology Ward	Pre	3	51.07	17.80
		Post	3	70.73	13.00
	Respiratory Care Unit	Pre	2	51.00	12.89
		Post	2	77.86	7.94
	Delivery room	Pre	3	46.85	10.54
		Post	3	72.84	5.30
	Operating room	Pre	8	53.68	6.43
		Post	8	81.77	7.38

SDCv.	Groups	Period	No.	PGMS	PSD
Years of Experience	(1 _ 5) yrs.	Pre	17	47.91	9.14
		Post	17	78.05	8.67
	(6 _ 10) yrs.	Pre	17	50.11	7.94
		Post	17	78.75	8.65
	≤ 11 yrs.	Pre	6	54.49	8.98
		Post	6	84.14	8.08
Training Courses Numbers	(1 _ 5)	Pre	30	49.69	8.12
		Post	30	78.80	8.48
	(6 _ 10)	Pre	8	48.14	10.89
		Post	8	78.49	9.28
	≤ 11	Pre	2	58.82	4.26
		Post	2	89.25	3.68

Source: Own authorship.

Table 4 present the analysis of covariance (ANCOVA) results for the nurse's enhancement that occurred due to the implementation of the proposed educational program, treated in relation to nurses' Socio Demographical Characteristics and Some Related variables (SDCv.), and (SRv.).

Table 4. Relationships by analysis of covariance (ANCOVA) to find out the relationship due to applying a proposed educational program and nurses' Socio Demographical Characteristics and Some Related variables.

Source of Variations	Type III Sum of Squares	d. f.	Mean Square	F Statistic	Sig. Levels	C. S. (*)
Intercept	2. 1970	1	2. 1970	383. 6	0. 000	HS
Gender	0. 0002	1	0. 0002	0. 026	0. 872	NS
Age Groups	0. 0058	2	0. 0029	0. 504	0. 611	NS
Marital Status	0. 0081	2	0. 0041	0. 708	0. 504	NS
Educational level	0. 0229	2	0. 0114	1. 996	0. 162	NS
Experience yrs.	0. 0008	1	0. 0008	0. 131	0. 721	NS
Work Place	0. 0896	8	0. 0112	1. 954	0. 107	NS
Training Courses	0. 0174	2	0. 0087	1. 521	0. 243	NS
Error	0. 115	20	0. 0057	R-Squared = 0. 605		
Total	25. 421	40				

(*) HS: Highly Sig. at $P < 0. 01$; Non-Sig. at $p > 0. 05$; Statistical hypothesis based on Analysis of Covariance (ANCOVA). Source: Own authorship.

The finding indicate that weak relationships are a proved with (SDCv.), and (SRv.) since no significant correlation were accounted at $p > 0.05$, and according to that, it could be concluded that the studied questionnaire's knowledge improvements concerning Blood Transfusion safety could be generalize on the studied sampling population even though differences within their {(SDCv.), and (SRv.)}. Table 1 represents

the descriptive statistics for the studied sample according to Knowledge Domains with significant comparisons

Discussion

The survey indicated that 57% of the sample comprised females, with 67.5% of them being married. Likewise, prior research has verified that most of the participating nurses were married [17,19]. More than half of the participants (52.5%) were aged between 25 and 29 years. The results show that a portion of young, employed individuals exhibited greater receptivity to clinical evidence. The findings of the current study are consistent with previous research, indicating that the majority of participants were aged 22-27 years. These studies also emphasized that younger participants were greater responsive to educational programs compared than older participants, highlighting emphasizing of engaging younger participants in professional development initiatives [20,21].

In terms of educational level, the majority of participants (57.5%) with a diploma from nursing institutes. This finding is consistent with a prior study in Mosul, conducted in intensive care units to evaluate nurses' knowledge of blood transfusion, which reported that 43.34% of participants were nursing institute graduates, making the highest educational level among the participants [22].

Regarding years of experience, 42.5% of participants had between (1 - 5) years of experience, as well as for those with (6 - 10) years of experience. This indicates that approximately (85%) of the participants have not more than 10 years of experience. This outcome is consistent with a study conducted in Sulaymaniyah, Iraq, which demonstrated a positive correlation between professional experience and knowledge among nurses and midwives, affirming their pivotal role in enhancing competence and expertise [23].

In clinical setting where the majority of staff have less than 10 years of work experience, structured education is the most effective means for developing intermediate knowledge into safe, sustainable knowledge and safe practice that positively enhance work outcomes [24, 25].

The biggest proportion of the sample comprised nurses employed in the emergency department (27.5%), followed by those in the operating room department, which accounted (20%). In contrast. The respiratory care department recorded the lowest segment of participation, whereas the dialysis unit ranked third, with four nurses representing (10%) of

all participant. The remaining departments were equally represented; include three nurses for each unit (7.5 %). The finding of the Kolmogorov-Smirnov test demonstrated statistically highly significant differences in the distribution of participants throughout the hospital departments. Accordingly, these findings confirm that the sample was adequately heterogeneous according to meet the specific requirement of each department, thus reinforcing the generalizability of the study's conclusion to the hospital as a whole. In other words, the choosing process was impartial about the nurses' working conditions. Previous empirical data has indicated the pivotal impact of the work environment in nurses' professional performance.

Al-Mutairi et al. (2022) confirmed that a supportive work environment, along with adequate staffing levels, is significantly associated with improved job performance among nurse's staff. hence contributing to enhanced healthcare [26]. The prior result underscores the necessity of selecting a representative sample from all departments of this study, as differing work contexts between departments can influence nurses' work results. Regarding the quantity of training courses attended by the nurses, a majority of them (75%) had participated in 1 to 5 training courses, with statistically significant differences were observed based on the number of courses attended, indicating that the foundational knowledge of nursing staff is affected by factors other than the number of courses attended. These findings corroborate the results of a comprehensive cross-sectional study by Chen, Zhang, and colleagues (2022), which examined the effect of an educational program on nursing knowledge within healthcare environments. Although some domains of knowledge showed improvement, no statistically significant improvement in overall knowledge was observed following completion of the educational program. Therefore, these results suggest that simply participating in training courses—particular general and non-specialized ones—do not necessarily lead to substantial knowledge enhancement. The relevance and specialization of educational programs are more important in augmenting nursing knowledge than their frequency or volume [27].

The finding shown in Table 2, demonstrated that the proposed educational program had a meaningful and statistically significant enhanced on improving the knowledge levels of the nurses who participated in this study concerning the safety of blood transfusion procedures within the sampling population studied for applying the proposed program. Before applying the program the evaluation of the nurses' knowledge was generally at moderate levels, according to the grand

mean of score (GMS) estimates values, which ranged between 0.473 and 0.559. The participants' knowledge regarding patient preparation was measured at (GMS = 0.473), the pre-transfusion role at (GMS = 0.475), post-transfusion procedures at (GMS = 0.559), and knowledge of transfusion reactions and their management at (GMS = 0.486). Overall knowledge during the pre-assessment period was evaluated at (GMS = 0.498), indicating a deficiency in knowledge pertaining to safe blood transfusion practices.

Moreover, enhancements were noted across all four examined knowledge areas following the completion of the training program, spanning from intermediate to advanced levels. The performance evaluation scores improved following the intervention in the knowledge levels for patient preparation (GMS=0.759), pre-transfusion (S=GMO.756), post-transfusion (GMS=0.838), and transfusion interactions and their management (GMS=0.818), resulting in an overall score of (GMS=0.793). The reported improvements were statistically significant ($P < 0.01$) across all examined knowledge domains, as demonstrated by matched-paired t-test analysis. The knowledge level rose from 49.8% pre-intervention to 79.3% post-intervention. Prior research has arrived to analogous findings. A study conducted in Hoshiarpur hospitals, Punjab, revealed a deficiency in nurses' knowledge of blood transfusion prior to a structured educational program. Subsequent assessments indicated significant enhancements in knowledge levels, thereby confirming the program's efficacy in addressing the knowledge gap among nurses concerning blood transfusion [24].

In addition, another study indicated a moderate degree of knowledge consistent with the baseline knowledge of the study group before the intervention. However, this level of knowledge exposed deficiencies in some domains related to blood transfusion, especially regarding proper blood storage at any temperature and the disposal of leaked blood bags, underscoring the critical need for continuous professional development [28].

These gaps and variations in foundational knowledge may be result from disparities in experience among nursing staff, healthcare institution policies, or a lack of in-service education and development. This problem may be ascribed to the lack of in-service training programs that provide developmental nurses with comprehensive knowledge, as well as equipping them with the skills requisite to manage any adverse reactions [29].

The results in Table 3 demonstrate significant enhancements in nurses' understanding of transfusion safety, due to the implemented educational program.

Prior to the implementation of the suggested program, the percentile grand mean of scores (PGMS) was at a reasonable level across all categories of nurses' socio-demographic characteristic variables (SDCv) and some related variables (SRv). This signifies a moderate baseline level of knowledge, irrespective of the demographic characteristics of the study participants—SDCv, including: (Age, Gender, Marital Status, Educational Level), as well as certain related variables—SRv, such as: (Years of experience, Workplace, and Number of prior training courses). Our results align with a research performed in Babylon, Iraq, including 100 nurses employed at "Imam Al-Sadiq Teaching Hospital and Al-Hilla Teaching Hospital" to evaluate their understanding of blood transfusion protocols. This study revealed no statistically significant correlations between the demographic features of the sample and their knowledge, with the exception of gender, which exhibited a statistically significant association with participants' knowledge in both the pre-test and post-test [30]. Moreover, a substantial enhancement in PGMS scores was noted following the program's implementation across all examined domains, with scores elevating to elevated levels post-intervention.

The findings of the current study, as presented in Table 4, demonstrate that the implemented educational program enhanced the knowledge of nurses at Tarmia General Hospital regarding blood transfusion procedures. This conclusion is substantiated by the analysis of covariance (ANCOVA) results, which indicate that the baseline effects stem from the application of the intervention (the training program), evidenced by significant relationships at $P < 0.01$. Conversely, the socio-demographic characteristics variables (SDCv) and some related variables (SRv) exhibited weak effects, without significant relationships at $P > 0.05$. This suggests that the respondents' knowledge levels improved uniformly due to the program, despite variations in their demographic and related characteristics. This further evidence of the suitability of the suggested training program for the all sampling population, which shown major differences in the aforementioned characteristics. This leads us to evaluate the extent to which the proposed training program is valid and comprehensive enough to application to the entire population, which may vary in the distribution of its demographic characteristics and other pertinent variables.

Furthermore, R-square, the value of Determination Coefficient at 60.5%, confirms that the enhanced knowledge is attributable to the intervention, thus underscoring the program's strong efficacy. This

underscores that well-designed training and development play a crucial role in standardizing information to the extent that it ensures safe practice and its positive effect on patients. The results of the current study align with those of a study conducted in Mashhad by Vaghar (2018), which examined the impact of an educational program on the knowledge of nurses in the city's hospitals regarding blood transfusion processes. Furthermore, the improvement in knowledge after the educational intervention was statistically significant, while demographic variables such as age, gender, and experience did not show any statistically significant link with post-intervention knowledge levels. Consequently, our findings support the evidence that structured educational programs play a significant role in enhancing knowledge, regardless of participants' demographic attributes, thereby leading to improved patient safety and elevated quality of healthcare [31].

Research by Shabbir et al. (2025), conducted over six months with a sample of 30 nurses in a private hospital in Lahore, demonstrated that educational interventions enhance nurses' knowledge regardless of their demographic attributes. This supports the notion that improved knowledge levels are influenced by the efficacy of the structured educational program, independent of other variable. Research on analogous teaching programs has shown that the chosen samples exhibited average to low levels of awareness concerning blood transfusion procedures [32].

Limitation

Despite the documented improvements in nurses' knowledge during this study, some limitations may hinder the generalizability of the results. The study was conducted using convenience sampling in a single healthcare facility in Baghdad (Al-Tarmia General Hospital). This limits the generalizability of the results to other healthcare facilities with different nursing environments and clinically distinct operational structures. Furthermore, the sample size (40) is relatively small, although statistically justifiable and capable of revealing differences within the study group. However, conducting a study in a larger number of centers with truly randomized designs would likely achieve higher results. Additionally, this study assessed nurses' knowledge levels using a self-administered questionnaire, which may not be readily applicable when nurses are actually interacting with patients.

Conclusion

The instructional program significantly enhanced the nurses' understanding of blood transfusion safety

across all areas, resulting in notable post-test outcomes. The knowledge level improved from 49.8% (PGMS) in the pre-assessment to 79.3% (PGMS) in the post-assessment. It appears to have effectively converted inconsistent information into dependable, evidence-based practice, hence enhancing patient safety. Furthermore, the results indicate that weak correlations exist between knowledge improvements and the studied respondents' (SDCv. and SRv), and no significant relationships were detected at $p > 0.05$. Consequently, it can be concluded that the knowledge improvements regarding blood transfusion safety, as assessed by the questionnaire, may be generalized to the studied population, despite variations in their (SDCv. and SRv).

CRedit

Author contributions: Conceptualization; Data curation; Formal Analysis; Investigation; Methodology; Project administration; Supervision; Writing - original draft; Writing-review & editing - Mohammed Ibrahim Humadi and Yaseen Mohammed Mussa.

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Not applicable.

Ethical Approval

The study was conducted in accordance with the ethical principles and research policies of Kirkuk University/College of Nursing. Administrative approval was obtained before data collection began, in addition to written consent signed by the participants after the study's purpose was clearly explained. Participants were also assured that their information would remain confidential and be used solely for scientific research purposes.

Informed Consent

It was applicable.

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All data, models, and code generated or used during the study appear in the submitted article.

Conflict of Interest

The authors declare no conflict of interest.

Similarity Check

It was applied by Ithenticate®.

Application of Artificial Intelligence (AI)

Not applicable.

Peer Review Process

It was performed.

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