International Journal of Advanced Nursing Education and Research
Vol.2, No.2 (2017), pp.25-34
http://dx.doi.org/10.21742/ijaner.2017.2.2.05

Enhancing Safe Medication Administration: Math Readiness Assessment and Learning Plan Pilot Study

Shelley Cobbett[1], Melanie Deveau[2] and Shauna Houk[3]

[1]Assistant Professor, Curriculum Implementation Lead,Dalhousie University School of Nursing, Halifax and Yarmouth Site's, Yarmouth and Halifax, NS, Canada
[2]Adjunct Lecturer, Dalhousie University School of Nursing- Yarmouth Site,52 Vancouver St., Yarmouth NS, Canada
[3]Assistant Professor & EB Bennett Professorship, Dalhousie University School of Nursing- Halifax Site, Halifax, NS, Canada
[1]shelley.cobbett@dal.ca, [2]melanie.deveau@nshealth.ca, [3]Shauna.Houk@Dal.Ca

Abstract

The Math Readiness Assessment (MRA) and Learning Plan Pilot Study provided the School of Nursing (SON) with evidence to guide future curriculum decisions to maximize student success, ultimately leading to improved patient safety in relation to accurate dosage calculation and safe medication administration. A pre-test, post-test one-group design was used to investigate initial math readiness in nursing students in preparation for attaining competency in dosage calculation and medication administration and the effects of a self-remediation learning plan. The pretest was the Foundational Numeracy Assessment (FNA) from safeMedicate™, with a demonstrated Cronbach's alpha of 0.891 and established criterion validity. The posttest was developed for use within this study and conceptually reflected the FNA. The pretest was administered to Year 2 undergraduate nursing students (N=227); those students who achieved less than 90% (n=166) were required to engage in a learning plan and write a math reassessment, the posttest. A paired sample t-test indicated statistically significant differences in student scores from the pre-test to the post-test (t= 17.25, df (136), <.0001) lending support for implementation of a learning plan that enhances mathematical competency.

Keywords: *Dosage calculation, Curriculum, Patient safety, Math competence*

1. Introduction

According to the Canadian Patient Safety Institute (CPSI), managing safety risks includes the ability to calculate, prepare and safely administer medications correctly, thus contributing to a culture of patient safety [1][2][3]. Annually one in every 18 people admitted to a Canadian hospital will suffer some kind of harmful event. Events associated with medication administration are among the most frequent and most harmful and account for 37% of adverse events in Canadian hospitals [4]. This pilot study was to assess foundational math competence and engagement in a learning plan prior to nursing students learning about accurate dosage calculations and safe medication administration. In an integrative review, Stoic [5] found insufficient evidence to support the implementation of any particular strategy aimed at

Article history:
Received (July 03, 2017), Review Result (September 09, 2017), Accepted (October 17, 2017)

ISSN: 2207-3981 eISSN: 2207-3159 IJANER

improving medication calculation skills for student nurses and advocated for more quality research related to math assessment and learning strategies. Evidence confirms that nursing students struggle with achieving foundational math competency [6] related to dosage calculations reinforcing that there is no single effective strategy used in nursing curricula [5]. The assessment and solid acquisition of these skills are essential for optimal student success and safety when calculating, preparing and administering medications.

2. Literature review

The issue of mathematical competency and its direct relationship to patient safety within the context of medication calculations must be considered in nursing education [7][8][9][10]. The importance of nurturing numeracy competence in nursing students is elevated when one considers that up to 40% of a nurses' workload involves medication administration [11][12] and approximately 33% of medication administration errors are attributable to incorrect dosage calculations [13].

Nursing students often perform poorly on math exams [6] and it is time for educators to reassess what core numeracy skills need to be mastered, how they are taught, assessed and translated into clinical practice so that adverse patient outcomes related to medication administration errors can be minimized [14]. Current literature reveals inconsistencies in the approaches used by academics to enhance the student nurse's medication calculation abilities [5]. The question remains, should numeracy competence be established prior to entrance into a nursing program or prior to learning dosage calculation and medication administration? A connection between students' previous mathematics skills and their perceptions of their ability to perform suggests that more attention should be paid to mathematics skills in general before entering nursing education [15].

Three key factors were identified which influence the student's ability to perform accurate medication calculations: mathematical ability, understanding the medication formula and being able to contextualize the link between the patient and the medication [16]. In the United States most accredited nursing schools require a math preparatory class and require applicants to successfully complete a mathematical competency exam prior to an offer of admission or conditional acceptance [17] but this is not common in Canada. Without foundational mathematical competence how can a student understand medication formulas or contextualize the link between the patient and the medication? The end result is that correct mathematical calculations must precede accurate and safe medication administration.

Ensuring patient safety must include a variety of factors, including perceived self-efficacy related to medication calculation [7]. It has been hypothesized that by fostering sound numeral competency, meaning and context and teaching drug calculation formulae while providing practical calculation examples, will demonstrate improved outcomes [9][10] for nursing students and ultimately improved health outcomes.

3. Method

3.1. Design

A pre-test, post-test one-group design was used to investigate initial math readiness in nursing students in preparation for attaining competency in dosage calculation and medication administration and the effects of a self-remediation learning plan. Our purpose was to assess foundational math competency prior to engaging in dosage calculations and medication administration learning, and to assess the efficacy of a self-learning plan for mathematical

competence. The pretest was administered to Year 2 undergraduate nursing students (n=227); those students who achieved 90% or greater (n=61) were not required to write a math reassessment, the posttest. Students achieving under 90% (n= 166) were sent a letter outlining directions as to how to obtain their pre-test mark and analysis report, with information related to self-remediation on those mathematical areas that their feedback report indicated that they needed to improve on and the date/time of the math reassessment test.

3.2. Data collection

Data collection consisted of two instruments: a Foundation Numeracy Assessment (FNA, safeMedicate™) and a Math Readiness Reassessment Test (MRRT). The FNA is an initial math skill assessment which is a computer based test developed and administered by safeMedicate™. The FNA is a 40 item, multiple choice test that assesses six areas: eight items related to both multiplication and division, and six items related to fraction conversion to decimal equivalents, decimal equations, integer equations and conversion of SI units. The FNA has demonstrated reliability with a Cronbach's alpha of 0.891 [8] and established criterion validity [2]. Within the current study, Cronbach's alpha for the FNA was 0.88. As of 2012, the FNA has been used as a diagnostic assessment with over 100 000 healthcare students and practitioners across three continents [18]. Analysis of the FNA results provided information related to student competence in foundational math skills, and where the most common errors occur- conceptual or arithmetical operation errors. Conceptual competence is defined as understanding the problem to be solved in context and arithmetical operation errors as using or applying incorrect arithmetic operation, e.g., dividing a fraction numerator into the denominator [19]. The benchmark for success on the test was set at 90%.

Students who did not reach the school-identified benchmark were provided with remediation information related to the areas that were tested on the FNA to enable them to complete self-directed preparation for a math reassessment. They were able to view their initial assessment results online to determine their score and what areas they needed to focus their remedial learning on (e.g., division, multiplication, fractions, SI unit conversion). Remediation information was provided to students who scored below 90% on the FNA, including a conversion chart for SI units and reference to the Kahn Academy (https://www.khanacademy.org/math/arithmetic-home) for the other five areas that were assessed.

As the FNA was designed as a baseline assessment to evaluate students' arithmetical operation and computation skills that are commonly used when calculating drug dosages it was not appropriate to use as a reassessment measure. "Use of the FNA supports faculty and novice students with understanding of any arithmetical 'dropped stitches' that the student enters the program with. These range from misunderstanding of arithmetical operations, including inappropriately dividing a fraction numerator into a fraction denominator, or inappropriate use of division/multiplication operations when converting SI units of volume or mass; and computational errors associated with multiplication or division of integers or multiplication and/or division errors when undertaking multiple computations of integers or decimals, typical of drug dosage calculation problem solving equation requirements." (Personal communication, Dr. Keith Weeks, September 12, 2016).

The posttest (reassessment) was completed using the Math Readiness Reassessment Test (MRRT) that was developed by the study team for use in this study. The MRRT is a 40 item, multiple choice paper and pencil test using the same test blueprint as the FNA. All students who scored below the 90% on the FNA were scheduled to write the paper-based MRRT. The

MRRT was reviewed by five university professors- four nursing professors and one professor from the Centre for Learning and Teaching, confirming face and content validity. Cronbach alpha for the MRRT was 0.87. Post-hoc question analysis was performed on the MRRT.

Reassessment was completed two to four weeks after the initial assessment. The wide range of reassessment time was related to students missing their initial assessment date to write the test and a second initial assessment time was arranged. For the most part, those students who wrote their initial assessment on the designated date had approximately four weeks to complete self-remediation.

3.3. Sample

The sample consisted of 227 undergraduate nursing students who were either in Year 2 of a 4-academic year BScN Degree Program or Year 1 of a 2-calendar year advanced standing BScN Degree Program and had not yet studied dosage calculation and medication administration. No sample demographic data was collected in this study.

4. Results

The FNA analysis was provided as an Excel file to the research team by safeMedicate™, including student total scores, student sub-section scores, computational versus arithmetic operation error scores, and aggregate percentages of item difficulty. The FNA total student score was copied to a SPSS IMB Version 22 data file for analysis. The MRRT analysis was provided as a tabbed output file by the University's Print Centre using MCEXAMS v. 2.3.9 and included student total scores, student sub-section scores, item bi-serial correlations, and item difficulty. Exam data was copied from the MCEXAM format to a SPSS data file for analysis. Frequencies and descriptive data analysis were used for the pre-test (FNA), the post-test (MRRT) and assessment area descriptions and indicators. A paired sample t-test tested the hypothesis that there was no difference between the FNA and MRRT scores.

Results of the FNA (n=226) indicated a mean score of 76.85%, median (77.50%), with a range of 32.5% to 100. Mark distribution is displayed in [Figure 1].

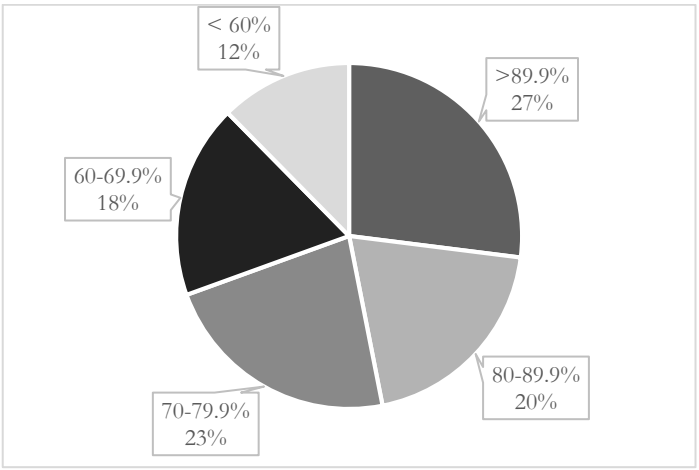

Figure 1. FNA total score distribution (n=226)

The sub-section (multiplication, division, fractions, integers, decimals and SI unit conversion) scores ranged from 58 % to 97%, with multiplication skills scoring the highest percentage of competence (97%) and decimals scoring the lowest (58 %) [Table 1].

Table 1. Pre-test FNA Sub-section results (n=226)

Assessment Area	# of Questions per Test (Total Number of Questions)	Total Number of Questions Correct	Cohort Percentage of Questions Correct
Multiplication	8 (1808)	1757	97
Division	8 (1808)	1395	77
Fractions	6 (1356)	1101	81
Integers	6 (1356)	1027	76
Decimals	6 (1356)	781	58
SI Unit Conversion	6 (1356)	886	65

Data was analyzed to assess whether student incorrect answer choices were related to computation errors (calculation errors), arithmetic operation errors (not setting the equation up correctly), or they self-identified that they did not know how to compute the answer. Out of all of the incorrect answers chosen, 65% of the errors were related to computational errors while 30% were related to arithmetical operation errors and 5% of students indicated that they did not know the answer [Table 2]. Five of the assessment errors had more students making computational errors than arithmetical errors and one assessment area, division, revealed that students more frequently made arithmetic errors when completing those questions than computational errors.

Table 2. FNA computational versus arithmetical errors

Assessment Area	# of Questions Answered Incorrectly (Total # of Questions)	Computational Error	Arithmetic Operation Error	Answered "Don't Know"
Multiplication	51 (1808)	45 (88%)	5 (10%)	1 (2%)
Division	413 (1808)	122 (30%)	280 (68%)	11 (2%)
Fractions	255 (1356)	157 (62%)	87 (34%)	11 (4%)
Integers	328 (1356)	294 (90%)	13 (4%)	21 (6%)
Decimals	575 (1356)	491 (85%)	22 (4%)	62 (11%)
SI Unit Conversion	462 (1356)	238 (52%)	212 (46%)	12 (3%)
TOTAL	2084 (9040)	1347 (65%)	619 (30%)	118 (5%)

A post hoc question analysis was completed on the post-test, the MRRT, which was developed for use in this study, to ascertain item discrimination (bi-serial correlation) and item difficulty (p-values). A point-biserial value of at least 0.15 is recommended, with items above 0.25 considered "good" items [20]. The classification of biserial correlation values used in this analysis are: poor, <.10, low, .10 - .19, acceptable, .20 - .29, good, .30 - .39, and 5 excellent, ≥ .40 [21][22]. All bi-serial correlation values were positive, indicating that those students who did better on the test more frequently answered the questions correct than those students who did poorer on the test. Thirty-two questions had acceptable, good or excellent item discrimination. When the emphasis on a test is for mastery-achievement, as is the situation with math competency in nursing students, it is not uncommon to have p-values in the 0.90 range. P-values with the MRRT ranged from 0.54 to 1.0, with 25 questions having a p-value of greater than .90.

Results of the MRRT (n=138) indicated a mean score of 86.27%, median 90.00(%), with a range of 40 to 100%. Mark distribution is displayed in [Figure 2].

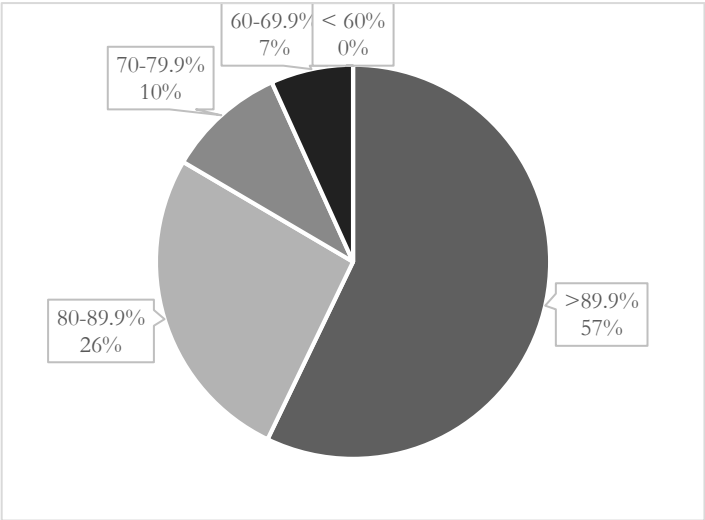

Figure 2. MRRT total score distribution (n=138)

The sub-section (multiplication, division, fractions, integers, decimals and SI unit conversion) scores ranged from 73 % to 98%, with multiplication scoring the highest percentage of competence (98 %) and SI unit conversion scoring the lowest (73%) [Table 3]. All assessment areas saw an increase in the cohort percentage of questions correct from the FNA to the MRRT.

Table 3. Post-test MRRT sub-section results (n=138)

Assessment Area	# of Questions per Test (Total Number of Questions)	Total Number of Questions Correct	Cohort Percentage of Questions Correct
Multiplication	8 (1104)	1087	98%
Division	8 (1104)	926	84%
Fractions	6 (828)	790	95%
Integers	6 (828)	726	88%
Decimals	6 (828)	630	76%
SI Unit Conversion	6 (828)	605	73%

There was a total of 137 paired pretest, posttest scores. A paired sample t-test indicated that there was a statistically significant difference in student scores from the pre-test (FNA) to the post-test (MRRT) (t = 17.25, df (136), <.0001). The pre-test mean was 70.29 (sd 11.79) and the post-test mean was 86.46 (sd 12.67). When comparing the assessment area categories from the FNA and the MRRT, greatest competence was demonstrated with multiplication in both assessments whereas the weakest area of competence was decimals in the FNA and SI unit conversion in the MRRT.

5. Discussion

Patient safety is directly related to numerical and dosage calculation skills of both nurses and nursing students [7]. Historically students have struggled in the skill of dosage

calculations and there has been little consistency in the approaches used by nursing educators to enhance the student nurses' abilities to understand the skill of dosage calculations [23]. It is imperative that foundational numerical skills of division, multiplication, ratios, fractions, and SI unit conversions be assessed prior to commencing drug dosage calculations [7]. Foundational mathematical skills should be assessed and reinforced through practice and reassessment throughout the program. Educators are encouraged to use consistency with their approach in teaching mathematical skills, for example, ensuring consistency and accuracy in administration of dosage calculation assessments [23]. Recent evidence shows that students use of technology in the form of e-learning were more likely to become competent in dosage calculations versus those who received paper handouts [7][23]. As a result of this study, we propose several curricula recommendations to promote optimal success for nursing students with the skill of dosage calculation, ultimately leading to enhanced patient safety.

It is essential that foundational numerical or mathematical skills be introduced early in the program [20]. The first recommendation is that nursing curricula need a foundational numeracy assessment at the beginning of the nursing program with identified learning resources for each of the six areas of mathematical competency as outlined in this report. Some organizations in the United Kingdom require any individual who is responsible for the administration and/or supply of medicines undergo an annual numeracy competency assessment [24].

The second recommendation is for one method of dosage calculations to be chosen and reinforced throughout the program (e.g., dimensional analysis) with faculty support to maximize the use of technology to facilitate this approach [5][23]. Optimizing the use of simulations and technology will provide the student with a more in-depth understanding of dosage calculations in the clinical context [16]. So rather than a student focus solely on the skill of calculation and administration, the context of the patient situation in its' entirety is included in the learning, for example, other medications, herbal use, possible adverse effects, body weight or health beliefs and practices.

Lastly the pilot study lends support for the final recommendation to be the integration of theory, lab and clinical practice leveled throughout the program related to dosage calculation and safe medication administration. For our school, the recommendation is to continue the use of the safeMedicate™ program not only prior to student learning about dosage calculation but also throughout the nursing curriculum. The safeMedicate™ program allows students to progress from foundational numeracy through to dosage calculation and administration in context, allowing the learning to be sequential - building on previously learned dosage calculation skill [16].

The program has a bank of over 1000 questions related to dosage calculation and faculty are able to individualize the assessment according to an area of focus (e.g., select pediatric related dosage calculation questions). As students' progress through the nursing program the level of difficulty and complexity increases, while maintaining a fair, consistent, valid and reliable approach to assessing dosage calculation competency across the entire curriculum. Authentic dosage calculation assessments within this platform are contextual rather than standalone dosage calculation problems. The use of realistic case studies (or simulation) gives the students a more in-depth understanding of dosage calculations in the clinical context [16]. Other researchers [25] advocated for a similar approach with scaffolding four strategies throughout the nursing program: medication calculation competency, the use of case studies to consolidate learning concepts, understanding the roles of the healthcare professionals involved in the medication cycle, and a series of short videos demonstrating the system factors associated with medication errors and their prevention.

The outcome of our pilot study has prompted us to explore foundational mathematical competency assessment prior to admission to the nursing program. It is naïve to assume that students enter the nursing program possess the pre-requisite foundational math competencies that are required for optimal success in dosage calculation and medication administration. Attention to these foundational mathematical skills prior to students engaging in dosage calculation have the potential to optimize student success, while minimizing adverse medication events in the health care setting.

6. Conclusion

There was a statistically significant improvement in math skills in those students who did not attain benchmark (90%) on the initial MRA therefore optimizing student success on dosage calculation. We are not able to directly link this finding to the remediation materials that we provided as part of this pilot study however we suspect that some of the increased competence that we assessed is related to self-directed student review of mathematical concepts, principles and practice questions. Approximately two-thirds of errors that students were making were related to computational (65%) and about one-third arithmetical operations (30%) errors, indicating that it was not the students' inabilities to set-up the correct mathematical formula, but rather their inability to accurately compute numbers (add, subtract, multiply and divide). The greatest arithmetic operation error was with division questions, indicating that a basic review of arithmetic operations theory may prove helpful to prepare students for dosage calculation proficiency. This finding has important implications for identifying at-risk students within our nursing program and has provided the evidence on which we have based our recommendations for nursing curricula as outlined in this article. The famous mathematician James Joseph Sylvester said "mathematics is the music of reason" and this music within nursing curricula's should be loud and clear!

References

[1] K. Macdonald, K. Weeks, and L. Moseley, "Safety in numbers 6: Tracking pre-registration nursing students' cognitive and functional competence development in medication dosage calculation problem-solving: The role of authentic learning and diagnostic assessment environments," Nurse Education in Practice, vol.13, pp.e66-e77, **(2013)**

[2] M. Sabin, K. Weeks, D. Rowe, B.M. Hutton, D. Coben, C. Hall, and N. Woolley, "Safety in numbers 5: Evaluation of computer-based authentic assessment and high fidelity simulated OSCE environments as a framework for articulating a point of registration medication dosage calculation benchmark," Nurse Education in Practice, vol.13, pp.e55-e65, **(2013)**

[3] Canadian Patient Safety Institute, "The safety competencies framework," Ottawa, ON, **(2009)**

[4] Canadian Institute of Health Information, Measuring patient harm in Canadian hospitals, Retrieved from https://secure.cihi.ca/free_products/cihi_cpsi_hospital_harm_en.pdf, **(2016)**

[5] S. Stolic, "Educational strategies aimed at improving student nurse's medication calculation skills: A review of the research literature," Nurse Education in Practice, vol.14, no.5, pp.491-503, **(2014)**

[6] J.D. Beall, T. Roebuck, and P. Penkalsky, "The relationship among math anxiety, mathematical performance, and math education in undergraduate nursing students," Honors Research Projects, Paper 76, Retrieved from http://ideaexchange.uakron.edu/honors_research_projects/76, **(2015)**

[7] M. McMullen, R. Jones, and S. Lea, "Patient safety: Numerical skills and drug calculation abilities of nursing students and registered nurses," Journal of Advanced Nursing Practice, vol.4, pp.891-899, **(2010)**

[8] P. Warburton, "Poor numeracy skills must be tackled to cut medication errors," Nursing Times, vol.106, no.9, pp.13, **(2010)**

[9] K. Wright, "Barriers to accurate drug calculations," Nursing Standard, vol.20, no.28, pp.41-45, **(2006)**
[10] K. Wright, "The role of nurses in medication administration errors," Nursing Standard, vol.27, no.44, pp.35, **(2013)**
[11] R. Meechan, H. Jones, and T. Valler-Jones, "Do medicines OSCEs improve drug administration ability?" British Journal of Nursing, vol.20, no.13, pp.817e822, **(2011)**
[12] S. Young, K. Weeks, and B. Hutton, "Safety in numbers 1: Essential numerical and scientific principles underpinning medication dose calculation," Nurse Education in Practice, vol.13, pp-e11-e22, **(2013)**
[13] M. Hodge, "Do anxiety, math self-efficacy and gender affect nursing students' drug dosage calculations?" Nurse Educator, vol.24, no.4, pp.36-41, **(1999)**
[14] S. Arkell and P. Rutter, "Numeracy skills of undergraduate entry level nurse, midwife and pharmacy students," Nurse Education in Practice, vol.12, pp.198-203, **(2012)**
[15] K. Roykenes and T. Larsen, "The relationship between nursing students' mathematics ability and their performance in a drug calculation test," Nurse Education Today, vol.30, pp.697-701, **(2010)**
[16] E. Coyne, J. Needham, and H. Rands, "Enhancing student nurses' medication calculation knowledge: Integrating theoretical knowledge into practice," Nurse Education Today, vol.33, pp.1014-1019, **(2013)**
[17] American Association of Colleges of Nurses, "Baccalaureate nursing programs," Retrieved from http://www.aacn.nche.edu/education-resources/bsn-article, **(2017)**
[18] K. Weeks, M. Sabin, D. Pontin, and N. Woolley, "Safety in numbers: An introduction to the nurse education in practice series," Nursing Education in Practice, vol.13, pp.e4-e10 **(2013)**
[19] K. Weeks, B. Hutton, S. Young, D. Coben, J. Clochesy, and D. Pontin, "Safety in numbers 2: Competency modelling and diagnostic error assessment in medication dosage calculation problem-solving," Nurse Education in Practice, vol.13, pp.e23-e32, **(2013)**
[20] S. Varma, "Preliminary item statistics using point-biserial correlation and p-values," Educational Data Systems, Inc. Morgan Hill, CA. Retrieved from https://eddata.com/wp-content/uploads/2015/11/EDS_Point_Biserial.pdf, **(2015)**
[21] M. Tarrant and J. Ware, "A comparison of the psychometric properties of three-and four-option multiple-choice questions in nursing assessments," Nurse Education Today, vol.30, 539-543, **(2010)**
[22] M.S. Trevisan, G. Sax, and W.B. Michael, "The effects of the number of options per item and student ability on test validity and reliability," Educational and Psychological Measurement, vol.51, pp.829-837, **(1991)**
[23] S.M.H. Revell and M.K. McCurry, "Effective pedagogies for teaching math to nursing students: A literature review," Nurse Education Today, vol.33, pp.1352-1356, **(2013)**
[24] National Patient Safety Agency, "Safety in doses London: National reporting and learning service," Retrieved from http://www.nrls.npsa.nhs.uk/EasySiteWeb/getresource.axd?AssetID=61626&, **(2007)**
[25] S. Latimer, J. Hewitt, R. Stanbrough, and R. McAndrew, "Contemporary issues. Reducing medication errors: Teaching strategies that increase nursing students' awareness of medication errors and their prevention," Nurse Education Today, vol.52, pp.7-9 **(2017)**

This page is empty by intention.