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Application of a model based on fuzzy logic for evaluating nursing diagnostic accuracy of students

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ABSTRACT

Purpose: To describe a model for assessing nursing diagnostic accuracy and its application to undergraduate students, comparing students' performance according to the course year.
Methods: This model, based on the theory of fuzzy sets, guides a student through three steps: (a) the student must parameterize the model by establishing relationship values between defining characteristic/risk factors and nursing diagnoses; (b) presentation of a clinical case; (c) the student must define the presence of each defining characteristic/risk factors for the clinical case. Subsequently, the model computes the most plausible diagnoses by taking into account the values indicated by the student. This gives the student a performance score in comparison with parameters and diagnoses that were previously provided by nursing experts. These nursing experts collaborated with the construction of the model indicating the strength of the relationship between the concepts, meaning, they parameterized the model to compare the student's choice with the expert's choice (gold standard), thus generating performance scores for the student. The model was tested using three clinical cases presented to 38 students in their third and fourth years of the undergraduate nursing course.
Results: Third year students showed superior performance in identifying the presence of defining characteristic/risk factors, while fourth year students showed superior performance in the diagnoses by the model.
Conclusions: The Model for Evaluation of Diagnostic Accuracy Based on Fuzzy Logic applied in this study is feasible and can be used to evaluate students' performance. In this regard, it will open a broad variety of applications for learning and nursing research.
Limitations: Despite the ease in filling the printed questionnaires out, the number of steps and fields to fill in may explain the considerable number of questionnaires with incorrect or missing data. This was solved in the digital version of the questionnaire. In addition, in more complex cases, it is possible that an expert opinion can lead to a wrong decision due to the subjectivity of the diagnostic process.

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1. Introduction

Nurses are legally responsible for nursing diagnosis (NDx) and treating human responses [1]. It has been demonstrated that NDx identification can improve the quality of interventions and the results achieved in patient care [2].

NDx is defined as "a clinical judgment about individual, family, or community response to actual or potential health problems/life processes. A nursing diagnosis provides the basis for selection of nursing interventions to achieve outcomes for which the nurse is accountable" [3].

Although it provides for better assistance, NDx is complex and prone to low accuracy due to its inherent subjective interpretations [1]. It is important, however, for the correct identification of signs and symptoms to support diagnostic reasoning, to establish diagnostic etiology, and to improve diagnostic accuracy [2].

In addition to some methods that have already been proposed to evaluate diagnostic accuracy [4,5], other methods are also required to teach diagnostic reasoning to students. The Lunney Scoring Method for Rating Accuracy of Nursing [4] consists of a seven-point scale designed to assess the "accuracy of the interpretation of clinical findings" of nurses. It is guided by the principle of sufficiency of data appropriateness of diagnosis and context in which they occur. The Nursing Diagnoses Accuracy Scale (NDAS) [5] was created based on the Lunney's scale. It also aims to assess the "accuracy of the interpretation of clinical findings" of nurses. It has four items that assess the presence, relevance, specificity and coherence of cues (defining characteristics) of the diagnosis. This scale was refined recently by its authors, and called NDAS – Version 2 [5].

Here, we present the application of one of these methods that is based on the theory of fuzzy sets [6]. Fuzzy logic allows for the construction of a linguistic model that provides a more natural way for students to learn clinical reasoning by using verbalization of all steps that are taken from a patient's signs and symptoms to their relationships to diagnostic possibilities.

This paper presents an application of fuzzy modeling, which is an approach to evaluate the performance of nursing students during the diagnostic process, this is, a tool of education assessment and training performance. This new method parameterizes fuzzy models through linguistic transformations from lexical expressions to categorical values. Then, the results of student diagnoses are aggregated through max–min composition and compared to those obtained by nursing experts.

In the present study, we used the Model for Evaluation of Diagnostic Accuracy Based on Fuzzy Logic presented previously in a nursing conference [6] and applied this to undergraduate students in their third and fourth years of the nursing course. Their abilities to correctly parameterize the model and their performance obtained from comparisons with those provided by nursing experts are also included, besides comparing students' performance according to the year of course.

2. Methods

2.1. Theoretical background

Artificial Intelligence has pursued the reproduction of human intellect capabilities with the use of computational systems. In this context, expert systems must be designed to represent human knowledge and, based on decision rules, to support decision-making; this is useful for standardizing nomenclature and improving the concordance among specialists. Using this type of system in the case of health care, it is expected that a professional can provide data from a patient and interact with a program that is able to indicate the most plausible diagnosis and, perhaps, also provide treatment suggestions, as if the system could act as a consulting specialist [7].

Although the application of fuzzy logic in the area of nursing remains limited, some studies have highlighted fuzzy logic in decision-support models in nursing practice [8,9]. The present study is representative of this use of fuzzy logic, although it also has implications for nursing teaching.

The theory of fuzzy sets (TFS) was developed during the 1960s by Lofti Zadeh [10]. This theory is based on the concept of partially true values that allows for the treatment of uncertainty, which is the case with NDx. While classical logic incorporates clearly delineated sets, fuzzy logic treats the boundaries between sets as gradual transitions. This introduces the concept of degrees of membership, whose values may vary from 0 to 1.

For example, while fever is either absent or present in classical logic, in fuzzy logic there is a gradual transition from a gradually decreasing membership to the non-fever state to a gradually increasing membership to the fever state with increasing temperature. Thus, this allows a model to be a guide to the correct diagnosis without regard for no-fever/fever, which is particularly interesting for clinical cases that present with low or intermittent fevers. By means of a symbolic system, models based on TFS can work with linguistic terms to describe the uncertainty of a phenomenon, such as *always*, *frequently*, *sometimes*, *rarely*, or *never* [10]. Thus, this approach can apply a mathematical treatment to human language and turns the interaction of a health professional with a model for diagnostic support into a straight forward task.

In addition, the notion of the 'degree of membership' allows for the reinterpretation of concepts. Rather than taking health and disease as opposites, where disease is the lack of health and vice versa, in fuzzy logic, these concepts are complementary and the passage from health to disease is gradual. In this way, a patient may present with either a progressive deterioration or a steady recovery to health, which is much more in agreement with reality [11].

Formally, if U is a set that represents the Universe, a fuzzy subset A of U is associated with the function μ_A: $U \rightarrow [0,1]$, which is usually called the membership function. The idea is that, for each $x \in U$, the $\mu_A(x)$ element indicates the degree to which x is a member of subset A, which indicates how much x is compatible with the characteristics that comprise A [12].

Classical set operations can be extended to the fuzzy sets, which also have membership degrees that are in the interval [0,1]. Thus, if it is assumed that A and B are two fuzzy subsets