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A Systematic Review of Ill-Defined Problems in the Intelligent Tutoring Systems in Virtual Learning Environments

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Abstract. Currently, defining the problems of intelligent tutoring systems in virtual learning environments has become a complex activity because of the misidentification of the problems as well as the correct planning for the use of this technology where the student is independent of the tutors, with this it is intended that students learn from the same classes regardless of the method they take for learning. This is how, thanks to the advance of information and communication technologies, several tools have emerged to help in education; one of them is called intelligent tutor systems, which are oriented to develop attractive environments for the student, integrating computer instruction and artificial intelligence. This article provides a systematic review of the ill-defined domains in intelligent tutoring systems in virtual learning environments.

Keywords: 3D Virtual Learning Environments, Ill-defined Domains, Intelligent Tutoring Systems, Systematic Literature Review.

1 Introduction

Ill-defined problems in virtual learning environments of tutoring intelligence systems do not allow the correct development of ill-defined complex learning domains [1] in the research [2] proposes to identify the processes that are used to solve ill-defined problems in multi-user virtual environments; these problems are characterized by [3] lack of information to help solve the problems, having a complex and imprecise objective and no clear strategies to find the solution to the problem, that is why there are problem domains with many solutions [4]. There are problem domains with many incomplete solutions without a clear procedure to evaluate a solution [5]. Some domains do not have a clearly defined theory with which to determine the outcome of the problem [6], with which it will be possible to determine the result of a problem by checking its validity [3]. Some domains do not have the correct information or are incomplete, implying the development of new analysis instruments [7] that are not fully developed, so it is impossible to have an exact solution to a problem.

According to the research conducted [6], ill-defined domains are problems that have many solutions and without a clear procedure for their solution, as well as not having a clear or complete domain theory to determine the outcome of a problem and determine its validity, other ill-defined domains are the analysis of incomplete and incorrect information from changing environments for decision making; likewise, ill-defined domains are defined as those that incorporate abstract concepts that do not have an absolute definition. Finally, it is also mentioned that these ill-defined domains include complex problems that cannot be separated into smaller and easier-to-solve subproblems. However, in another study [8], it is mentioned that there is no clear distinction between ill-defined domains and well-defined domains, causing difficulties in choosing the right educational and technological approach; therefore, a classification of solution strategies is proposed, which is divided into five classes: the first has a single solution, the second is a solution strategy with different solutions, the third is made up of

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typical strategies that do not have a new and relevant solution, the fourth is a large number of verified strategies and the fifth is a solution that cannot be automatically verified [9], machine learning and software development of intelligent tutoring systems applications to non-cognitive skill domains, where new designs and strategies for learning in the development of intelligent tutoring systems are proposed [10]. The development of intelligent tutoring systems has been evolving to create virtual platforms for the development of educational activities through the collaborative software of 3D Virtual Learning Environments that help strengthen learning inside and outside the classroom [11]. Through intelligent tutoring (ITS), students in institutions that use this technology have a better academic performance with favorable results, improving the learning experience through this technology [12] and improving the learning experience through augmented reality, which shows virtual images that surpass the physical world [5]. However, as a technology in a maturation stage, poorly defined domains exist in these virtual environments [4]. These intelligent tutoring systems promise many benefits in the education of systems that work in ill-defined domains, especially simulation systems [1,4]. Complex and ill-defined learning domains make it difficult to teach the technical and non-technical skills mobilized during a critical situation within virtual environments, identifying that some aspects of ill-defined domains are not mentioned in the domain literature. There is no in-depth study of teaching behaviors that introduce technical and non-technical skills in a virtual world [13], one of the most important benefits of the interaction of technology with augmented reality is motivation, ease of interaction, development of cognitive skills, improvement of short-term memory and making lessons more enjoyable, which makes the overall experience stimulating and engaging.

Faced with this problem, the need to conduct a systematic literature review (SLR) arises, allowing to know the problems of poorly defined domains in virtual learning environments of tutoring intelligence systems. This research aims to determine possible solutions for the correct approach to the domains of virtual learning environments. The results obtained from this bibliographic research will be validated by the researchers, who can propose solutions for the correct heating of the domains in future works.

2 Related Work

Concerning this topic [6], a study published in the IEEE Digital Magazine proposes the development of a Multiparadigm Intelligent Tutoring System for robotic arm training in which it was mentioned that an ill-defined domain does not have a clearly defined theory is a problem to test its validity for the development and reach a solution to the problem, likewise, ill-defined domains have many debatable solutions and without a concrete procedure to reach the solution. Likewise, these ill-defined domains do not have clear concepts, remaining in indeterminate abstract concepts that lack an absolute definition, likewise, the problems are too complex that cannot be divided into smaller independent subproblems that are easy to solve.

Within this order of related works, we have the research published in the Handbook of Learning and Cognitive Processes [3], where the author states that a domain is poorly structured when the information is incomplete or not relevant to support the research, the objectives set for the development of the work are complex and imprecise, and it does not have well-defined strategies with which to solve the problem.

Similarly, in the research [8] published in the IEEE Journal where a continuous operationalization was developed between well-defined and ill-defined problems for educational technology where it is mentioned that one of the most effective ways to learn is through the development of educational systems that are intended to help solve ill-defined problems, where researchers agree that there is no distinction to identify an ill-defined problem from a well-defined one. However, in this fine line of research, it is possible to identify when the problem presents difficulties when choosing an appropriate technological approach, so in this research, five strategies were proposed which will allow for identifying ill-defined problems, one of these strategies in which the problem has a single solution, there is no discussion of the problem or options to solve the problem; likewise one of the most relevant strategies is that there are several solutions, but none is concrete, or the strategies proposed only offer typical and traditional solutions. Unlike the strategies that go beyond what is foreseen in the research work or whose correctness cannot be automatically verified, the implementation of these strategies in the identification of ill-defined problems helps researchers to develop modeling techniques suitable for educational systems and also offers technological learning that helps communication in a more precise way in the face of ill-defined educational problems.

On the other hand, in the research, [9] found in the Springer digital research library where an intelligent tutoring system for psychomotor development is developed due to recent advances in education automation and software development is extending intelligent tutoring systems to non-cognitive skill domains, currently new design architectures and tutoring strategies were developed, this article was focused on a course on Selfit which is an intelligent tutoring system for psychomotor development, which focuses on anatomical adaptation as the first phase. This module was developed based on the multi-armed bandit contextual algorithm for the online generation of teaching sequences to overcome the multiple problems that arise in online education, such as lack of teaching time, the complexity of user characteristics or motivation management, for the development of this research was developed in a virtual environment, applying different strategies in systematic experiments, as also the Selfit is being tested in a group of students who find it as an intuitive, modern, attractive and easy to use the system.

In the research published in the digital repository Springer [2] proposes to design failure to foster success: productive failure in a multi-user virtual environment to solve complex problems in order to gain an understanding of the initial stage of an effective failure treatment, this research is focused on how students solve complex or ill-defined problems in VirtualSingapura, a multi-user virtual environment, a mixed method approach employing conversation analysis, questionnaires and pre-, mid- and post-tests was used in this research. Complex problems, by their very nature, are difficult for students to connect to, and this project will focus on the initial cycle of a productive failure treatment to develop a series of design considerations that teachers can implement in a learning environment that will help students develop strategies for solving ill-defined domains.

The research developed at the Laboratory of Educational Informatics and Audiovisual Media [14] presents a solution to the teaching style selection problem in the Intelligent Tutoring Systems framework, where a neural network is proposed to identify which is the most feasible method for each student.

On the other hand, in research published in the IEEE digital research library. [8] proposes to operationalize the continuum between well-defined and ill-defined problems for educational technology; therefore, researchers have developed educational systems aimed at solving ill-defined problems, so most researchers agree that there is no sharp distinction but a continuum between well-defined and ill-defined. For the resolution of ill-defined domains, the five-stage classification is proposed to allow researchers to choose or develop an appropriate modeling technique for educational systems, providing the learning technology community with a means of communication to talk more precisely about types of ill-defined educational problems.

The article published in the digital repository Dialnet [15] mentions that technology has made inroads in education by developing a more interactive learning environment, which evidences the ill-defined problems that arise in virtual learning environments, which may not have the necessary information to solve the problems, or may have many alternatives but none is concrete, this being a research work that aims to present the most relevant and representative aspects of intelligent tutoring systems.

As noted in the research published in the Iberoamerican Journal for Educational Research and Development [16] states that the educational sector is changing and is evolving and implementing new technologies; among them, the virtual platforms for the development of educational activities where the most used software currently used for these activities is 3D Virtual Learning Environments, however, due to the technological evolution new didactic tools have been developed to strengthen education, but they lack the necessary information to solve the problems, or the information is incomplete; likewise the objectives are vague and lack clear strategies to find the solutions causing with them the increase of more problems in the research.

Based on the studies selected in the literature review, it was identified that there is not much research on the poor approach to problems in virtual learning environments, for the research is intended to analyze the most common problems that occur in such learning environments. This research was obtained from the digital repositories of Dialnet, Scopus, IEEE, RIDE, and Google Scholar, among others. During the selection of the articles, the ill-defined problems in ITSs focused on individual learning environments are taken as a criterion. Identifying that some of the articles selected for the research do not have enough information is why they are not considered as a reference. The objective is to elaborate a systematic review of the literature on ill-defined problems in intelligent tutoring systems in 3D virtual learning environments.

The 28th International Conference of the Florida Artificial Intelligence Research Society is worth noting [1], where the authors proposed an approach for displaying and graphing machine-readable expert models for Intelligent Tutoring Systems and virtual environments for education, which he based on previous development work, for the implementation of new ITS features in complex and ill-defined learning domains. This constraint-based expert model is used with a real-time interpreter to make accurate, real-time observations of how learners behave in ill-defined domains. This research is of great relevance and will serve as a guide for the present investigation, which will identify the structure and elements for the solution of ill-defined domains, thus extending the research and improving the research paradigm.

3 Research Methods

For the initial phase of the systematic literature review (SLR), a protocol is proposed to guide the review, following the guidelines of the methodology proposed by Kitchenham [17], which has three phases for development and is described as follows i) planning of the review, identifying the objectives and validating the review protocol; ii) execution of the review, carrying out the protocol defined in the previous phase; and iii) dissemination of the review, preparation of a report with the results of the review.

3.1 Planning the Review

Research Question. The present review aims to elaborate a systematic literature review to understand the ill-defined problems in Intelligent Tutoring Systems in virtual learning environments. The research questions posed to achieve this objective are:

RQ1. How do you identify an ill-defined problem from a well-defined one?

RQ2. What are the main ill-defined problems in 3D virtual learning environments?

RQ3. What are the possible solutions for a correct approach to the domains of 3D virtual learning environments?

Data Source and Search Strategy. The automatic search of the primary studies was carried out in the digital libraries of Dialnet, Scopus, Springer, IEEE, RIDE, Google Scholar. Also, manual searches were performed in the most significant conferences, workshops, journals and books that address as the main theme of the ill-defined problems in Intelligent Tutoring Systems in virtual learning environments

Tabla 1. Search string.

Concept	Sub-string	Connector
Ill Defined Domain	Tutoring Intelligent Systems	AND
	Smart Tutoring Systems	OR
Ill Defined Problem	3D Virtual Learning Environments	AND
	Virtual worlds	OR
Ill-Defined	Virtual Learning environments	AND
Virtual learning environments	Intelligent tutoring systems	AND
Ill-defined	Intelligent tutoring systems	AND

Search string:

(Ill Defined Domain*) AND (*Tutoring Intelligent Systems OR Smart Tutoring Systems*) (*Ill Defined Problem*) AND (*3D Virtual Learning Environments OR Virtual worlds *) (*Ill Defined*) AND (*Virtual Learning environments*) (*Virtual learning environments*)AND (*Intelligent tutoring systems*) (Ill) AND (*Intelligent tutoring systems*)*

Selection of Primary Studies. The primary studies obtained from the automatic and manual search were thoroughly evaluated for compliance with all research parameters, based on the articles' title, abstracts, and keywords. Discrepancies in the selection of studies were resolved by consensus after a review of the full article.

Primary studies meeting at least one of the following inclusion criteria were included:

IC1. Primary studies that address the main problems that cause a domain to be poorly defined.

IC2. Primary studies mentioning the main solutions for the correct definition of domains in virtual learning environments.

Primary studies meeting at least one of the following exclusion criteria were excluded:

EC1. Editorials, forewords, opinions, discussions, interviews, news, advertising, panels or posters.

EC2. Studies published in different digital libraries and are duplicates of other works.

EC3. Items for which the complete document is not available.

EC4. Short articles with less than two pages.

Quality Assessment of Primary Studies. The quality of the studies selected for the present investigation was assessed with a checklist consisting of three questions Table 2. Each question was assessed using a scale between 0 and 1. The scores obtained from these questions were summed to calculate the score for each study, which served only to order the studies according to scientific relevance and correctly address the presentation of the systematic review results.

Tabla 2. *Quality checklist.*

No.	Question	Answer and score
QAQ1	Other authors have cited the main study.	More than 5 citations, very relevant (1) Between 1 and 5 citations, relevant (0.5) No citation, irrelevant (0)
QAQ2	The main study has been published in a relevant journal or conference.	Highly relevant (1) Relevant (0.5) Irrelevant (0)
QAQ3	The main study includes an evaluation of the proposed solution.	Yes (1) No (0)

Data Extraction Strategy. Table 3 shows the data extraction form that was applied in the primary studies. The criteria of this form facilitated the collection and systematization of the information, as well as making it possible to answer the questions posed in the research to organize the results of the review correctly.

Table 3. *Data extraction form.*

RQ1. How do you identify a poorly defined problem from a well defined one?	
EC1.	Most common problems
EC2.	Common strategies for identifying poorly defined domains.
EC3.	Methodology used
RQ2. What are the main ill-defined problems in 3D virtual learning environments?	
EC4.	Approach used for the research
EC5.	Type of research
EC6.	Techniques used for the approach of the problem.
RQ3. What are the possible solutions for the correct approach to the domains of 3D virtual learning environments?	
EC7.	Type of solution applied

Methods of Analysis and Synthesis. The methods used for this research are: i) quantitative, based on the construction of bar, pie and bubble graphs to represent the frequency of responses for each extraction criterion or combination of extraction criteria; and ii) qualitative,

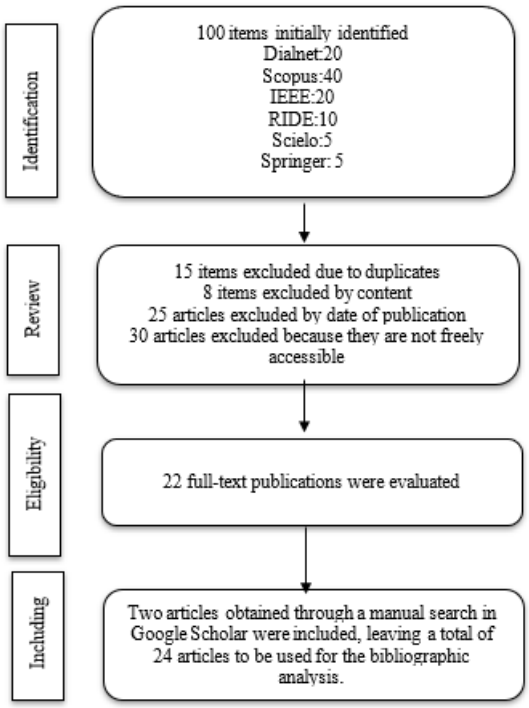
due to the description of the most relevant proposals, highlighting the gaps and opportunities existing in the research.

3.2 Conducting the Review

Through the search strings used to collect and select the articles that will be used for the execution of the literature review. Carrying out the following processes (**Figure 1**).

a. Search for articles. With the help of search strings executed in each of the selected virtual libraries. Obtaining as a result 100 primary studies.
b. First selection. The abstracts and key words of the selected studies were evaluated using the inclusion and exclusion criteria. As a result, a total of 22 studies were obtained.
c. Second selection. The discrepancies in the selection of the articles were resolved by consensus, where all the documents were reviewed again. As a result, the number of studies increased to 24. A manual search was also carried out, with which three additional studies were added.
d. Quality assessment. Finally, a checklist was used to evaluate the quality of the studies. An ordered list of studies was obtained according to relevance.

Figure 1*. Item selection diagram*



4 Results and Discussion

Immediately after completing the systematic review by applying the corresponding protocol, 24 primary articles were obtained. These were the most relevant ones concerning the topic, such as the review of ill-defined problems in intelligent tutoring systems in 3D virtual learning environments. Figure 2 shows the distribution of the articles selected for the literature review by year. Observing that the largest amount of research was developed in the year 2021 (8 articles), evidencing that it was the year that more articles were developed referring to the research topic. However, unlike the other years, a low rate of publications was observed, affirming that the topic of study does not have the interest of the researchers, being this a serious problem, because it is a topic of great interest that has to be analyzed to solve the ill-defined problems of the intelligent tutoring systems that are currently being developed.

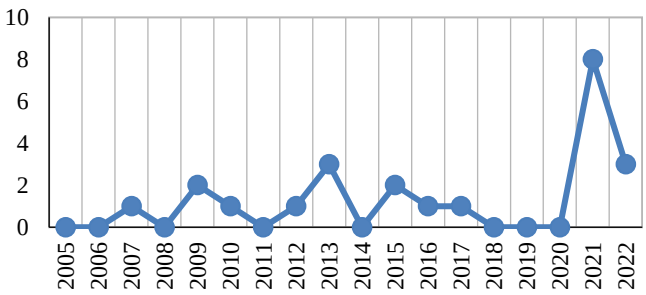


Figure 2. *Year of publication*

Now, in the articles selected for the literature review, it was observed that researchers prefer to publish them in digital journals, resulting in a total of 21 relevant articles related to

the topic of study, since it is a digital site that is available to all and are easier to find by researchers, unlike the 3 conferences that were obtained through the extraction of information.

Similarly, Figure 3 shows the results of the quality assessment. As a result, in question QAQ1, eleven articles were found to be relevant to the topic of study, followed by a total of nine highly relevant articles. Finally, five articles selected for the literature review were considered irrelevant. In question QAQ2, fourteen articles were found to be very relevant, nine were considered relevant, and only one was not relevant. Finally, in question QAQ3, twenty articles selected for the literature review were identified as evaluating the proposed solution, while four articles had no proposed solution.

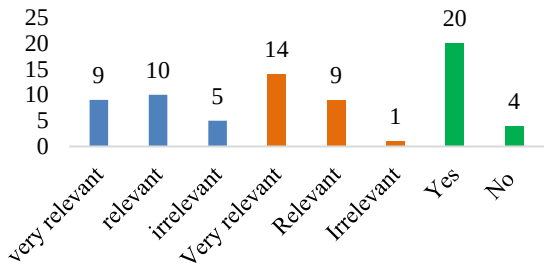


***Figure 3**. Evaluation of the quality of primary studies*

The following subsection analyses show the results obtained through the research questions and information extraction criteria.

RQ1. How do you identify an ill-defined problem from a well-defined one?

The results obtained for each research question and their extraction criteria are shown below.

EC1. Most common problems. The most common problems that mostly exist in ill-defined problems were identified through this extraction criterion. It was found that 36.84% of the ill-defined problems are because the researcher uses typical and repeated strategies. Therefore, intelligent tutoring systems in virtual learning environments have no relevance, in the same way 28.95% of the studies do not have the necessary information to support the study, and it was also observed that 18.42% of the tutoring systems do not have a valid solution that has been verified and is suitable for use. Finally, 15.79% of the studies selected for this literature review show that the problems have only one solution and that there are no other solutions in case the first one does not work.

EC1. Most common problems	Relevant studies	Quantity
Incomplete information	[6,7,11,12,14,18-23]	11
Problems with a single solution	[2,9,14,18,21,24]	6
Problems with typical strategies	[1,4–7,9,11,14,20,25–28]	14
Problems whose solution is not verified	[1,5,8,12,22,24,27]	7
TOTAL		38

Among the most relevant studies in which the ill-defined problems were identified, we have the investigation [6] of a multiparadigm intelligent tutoring system for robotic arm training where it is mentioned that domain knowledge is achieved by adoption through the construction of a cognitive model, the specification of constraints, the integration of an expert system and the use of algorithms through data mining to learn domain knowledge, however, some ill-defined domains use individual paradigms, thus limiting the resources needed for implementation and tutoring support. [2] In this way it can be defined that incomplete information within an investigation tends to generate solutions that have no answer or unique solutions, therefore, ill-defined problems are presented, as well as problems that are developed with traditional strategies or the solution is not verified.[12]. Finally, one of the studies selected for the investigation [4] mentions that the investigations of systems working in poorly defined domains, especially simulation environments, should present more ideas to understand how these systems work through tutorials in simulated environments.

Common strategies to identify poorly defined domains. This extraction criterion identified that the common strategies to identify an ill-defined domain are that the systems have very deficient solutions that do not support the research or do not solve the problem (41.94%), another strategy to identify ill-defined problems is that they do not have enough information regarding the subject of study (32.26%). Finally, with 25.81%, it was observed that the solutions to solve the problems are very costly and take a long time to develop (25.81%).

EC2. Common strategies for identifying poorly defined domains.	Relevant studies	Quantity
Deficient solutions	[2,4–6,8–11,21,22,26,27]	13
Tailor-made solutions, investing time and high economic values	[1,10,11,14,20,24,27]	8
Lack of information	[1,7,11,12,19,20,23,25,27]	10
TOTAL		31

Among the most common strategies to identify ill-defined domains, deficient solutions do not have the necessary information to solve the ill-defined domain [27]. Similarly, there are solutions tailored to the problem that are too costly or take too long to develop. [1,9,11]. Finally, the poorly defined domains have no or minimal information that does not allow the problem's solution to be investigated [1,7,13,25]

RQ2.What are the main ill-defined problems in 3D virtual learning environments?

EC3. Approach used for the research. According to this extraction criterion, it was identified that the most used approach in the definition of the problems of intelligent tutoring systems in virtual learning environments is the mixed approach, with a total of 45%. In comparison, the multiparadigm approach has a percentage of 20%; likewise, other approaches that are not widely used as is the trial-error, pedagogical methods, genetic algorithms approach and approaches oriented to cognitive psychology, have 20% of the studies selected for research and 15% of the selected studies have a constructionist approach.

EC3. Approach used for the research	Relevant studies	Quantity
Multiparadigm approach	[5,6,8,13]	4
Mixed method approach	[1,2,7,11,22,24,25,27]	9
Constructionist approach	[18,19,26]	3
Another	[10,12,20,21]	4
TOTAL		20

Among the most used paradigms for the development of systems with ill-defined domains, we have a mixed approach [2,22] where they focused on how students solve ill-defined problems in Virtual Singapura, which has a multi-user virtual environment through conversation analysis, questionnaires and pre-, intermediate and post-tests, aiming to inform theory about productive failure [21]. Similarly, there is the genetic algorithms approach to feature selection, equitable access to intelligent tutoring systems through digital integration, an adaptive pedagogical agent based on the theory of a reading application for elementary school students.

EC4. Type of research. Now, in this extraction criterion, it was evidenced that the most used type of research in these ill-defined studies is documentary research, with a total of 33.33%, followed by observational research, which has a total of 27.27%, as well as experimental research with 18%. Finally, we have qualitative and quantitative research with 12% and 9.06%, respectively.

EC4. Type of research	Relevant studies	Quantity
Qualitative	[1,23,25,26]	11
Quantitative	[2,26,27]	13
Observational	[1,5,7,10,11,14,20,22]	8
Experimental	[4,5,9,11,22,24]	6
Documentary	[4,6–8,12,14,18,19,21,24,27]	38
TOTAL		11

In this way, it was identified that most of the collected articles worked with the type of documentary research with which several works related to the topic of the study were identified and a bibliographic review was developed [4,21,27], which was used to obtain the most relevant information for the research, in the same way, through experimental research, intelligent tutoring systems were developed [4,5,9,22Furthermore, intelligent tutoring systems were developed for students and teachers, which helped solve the ill-defined problems identified in their research [1] where they researched the observation of students in how they solve ill-defined problems in their daily tasks.

RQ3.What are the possible solutions for the correct approach to the domains of 3D virtual learning environments?

EC5. Type of solution applied. According to this extraction criterion, it was evidenced that the types of solutions applied in ill-defined problems in intelligent tutoring systems in virtual learning environments are virtual environments with 34.21%. In comparison, in 28.95%, intelligent tutoring is applied, as opposed to 21.05% are expert models and with 15.79%, there are other solutions such as three-dimensional

learning environments, adaptation models and cognitive models, use of digital paper and 3D virtual learning.

EC5. Type of solution applied	Relevant studies	Quantity
Intelligent tutoring	[4–6,9–11,14,19–21,26]	11
Virtual environment	[2,5–7,9,11,12,18,20,22,25–27]	13
Expert Model	[1,2,8,11,14,23,24]	8
Others	[10-12,21,26,27]	6
TOTAL		38

According to the studies selected for the development of the present research, virtual environments are considered the most used for the solution of ill-defined domains, so it was also observed that intelligent tutorials [9,19,20,26] fot the learning of these ill-defined domains. Finally, it was evidenced that some of the solutions applied to solve these ill-defined problems are three-dimensional learning environments, where students interact in a virtual environment, where they can learn in an interactive environment [26], and where students interact in a more technology-friendly environment. On the other hand, there are adaptive and cognitive models[12] in which teachers and students adapt to these models of virtual intelligent tutoring systems.

5 Conclusions and Future Work

The results allow concluding that as time goes by, new strategies appear to try to solve the ill-defined domains, therefore new solutions arise, such as intelligent tutoring or three-dimensional methods that will help to solve the shortcomings presented in the intelligent tutoring systems in virtual learning environments in more agile and efficient way, allowing the user to have a more comfortable and friendly interaction with the software.

Due to the lack of interest on the part of researchers regarding the topic of study and the lack of research found in the literature review, it is concluded that ill-defined problems are a topic that should have more interest on the part of researchers because there are no strategies developed for a correct definition of a problem, with which these ill-defined domains can be minimized in intelligent tutoring systems in virtual learning environments.

It is evident the shortcomings in the ill-defined domains or problems due to the lack of research to find a solution to these problems, which is why it is proposed, as future work, the development of a prototype through the Unity game engine which will build a virtual learning environment in 3D that will help in the detection of possible solutions through genetic algorithm techniques for ill-defined problems or domains.

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