

Characteristics and Application of Intelligent Tutoring Systems: A Review

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Abstract— Recently, technology has developed rapidly, this has an effect on the integrated education system model with artificial intelligence techniques. Such educational models are known as Intelligent Tutoring Systems (ITSs). This paper aims to evaluate the characteristics of several ITS models that are applied to various fields of education. The original studies from 2009 to 2021 were extracted from the ACM Digitally Library, IEEEExplore, Scopus, Google Scholar, Science Direct, and Springer databases. From the search on the database, 26 papers were obtained which were used as the focus of evaluation based on the inclusion criteria as stated in the Kitchenham framework. From the results of the evaluation, the conclusion is that computer science is the largest field that applies ITS (50%). Meanwhile, artificial intelligence techniques are applied in ITS, the greatest frequency is NLP-based techniques (30.7%) and intelligent agent techniques (26.9%). These techniques are proven to be able to provide guidance and instructions according to user needs, evaluate processes learning for learners, defining new student models, and categorizing learners on ITS.

Keywords—Artificial Intelligence; Education; Intelligent Tutoring Systems; Learners.

I. INTRODUCTION

The e-learning system that is used as a complement to the learning process has enormous urgency and contribution. This role is more evident in the case of lockdown scenarios, such as the one we are experiencing now because of the COVID-19 pandemic. Several software systems are available that are intended to assist the online learning process, for example, the Learning Management System-LMS, Virtual Learning Environment-VLE, and others. The development of this online learning system is known as the Intelligent Tutoring System (ITS).

The integration of computer programs and computer systems that can adapt learning activities and strategies based on student characteristics and needs is defined as an intelligent tutoring system (ITS). ITS is expected to be able to carry out functions in the tutoring process including presenting information to be learned. ITS must also facilitates the things that educators want to convey to students, including giving questions, giving assignments, giving quizzes or exams, and feedback. ITS goal is to shape

cognitive changes and learning motivation in students. To achieve this goal, ITS combines Artificial Intelligent (AI) techniques with educational methods to define the content model (subjects to be taught) and the learning strategies that each student will use; that is, they determine the "what" and "how" the learning process takes place[1][2]. In recent years, the use of artificial intelligence (AI) methods, especially machine learning (ML), has developed in learning systems. ITS has a classical architecture with four modules, namely an expert module, a student diagnosis module, an instruction module, and a user interface module[3]. The first module, namely the expert module, includes the knowledge students want to have in learning (domain knowledge)[4]. In this module, analysis is carried out in each student activity in the learning process and is combined with problem-solving techniques faced by students during learning. This activity is known to human experts[5]. The second module, namely the learner diagnosis module or learner model, is built by some components such as the tier of knowledge, actions, responses, behavior, the way of learning, and other information about students collected in the learning process system.[6]. The third module is an instruction module. In some literature, it called a pedagogical module that detects knowledge deficiencies in learner and concentration on teaching strategies and methods to compensate for the lack of knowledge in a particular area. In this module the point is to provide feedback, directions, make recommendations, navigate learning pathways, and present adaptive educational content.[5]. The next module is the user interface which is the interface between the user and the system. This user interface is also a control and communication tool in ITS.

Several studies have been carried out on e-learning systems to enhance adaptive learning [7]. Other research have proved the effectiveness and usefulness of the ITS system and intelligent guidance game systems [8][9][10]. We've got a survey on the review of the articles available; it turns out that there are some questions that were not answered. Therefore, the aim of this study is to examine ITS which is developing in all fields of education, to gather comprehensive information about its characteristics and applications.

II. LITERATURE REVIEW

From several literature reviews, it is known that the Intelligent Tutoring System (ITS) consists of a set of programs that describe student knowledge and have a function for dialogue between them. ITS was originally called the Scholar [11]. There are several main features that must be owned by ITS, namely ITS must be adaptive with students, can exchange information with students, and have a special knowledge domain [12]. This was later developed by [13] which states that the ITS architecture consists of four modules, namely communication, tutorials, students and experts.

III. METHODOLOGY

In order to provide characteristic and applications of ITS, this research conducted through a Systematic Literature Review (SLR) method proposed by Kitchenham and Charters [14]. This method consist of several steps, which are: determining research question that was explained in the first part of this paper known as the introduction, determining research sources, defining patterns of index terms for the search process, defining inclusion and exclusion criteria, extracting data, and answering research questions by analyzing findings.

A. Research Questions

The following research question is addressed in this study ;

RQ1 : In which educational fields has ITS been designed?

RQ2 : In ITS development, what AI techniques have been applied?

RQ3 : what are the characteristics of ITS implementation at each level of education?

B. Search Process

The first step is defining the source of literature to find out which articles are related and become current trends related to ITS characteristics and applications, it is necessary to select journal articles. The following databases were used to find relevant articles :

- ACM Digital Library (<https://dl.acm.org>)
- IEEEExplore Digital Library (<http://ieeexplore.ieee.org>)
- Science Direct (www.sciencedirect.com)
- Springer Link (link.springer.com)
- Google Scholar (<https://scholar.google.com/>)
- Scopus (<https://www.scopus.com/>)

The pattern of keywords used in this study is to trace the research studies in spite of answering the research question using Boolean operator to screen the data, so we can define the priority to search in the data base. The Boolean operator that we used in this paper [15], using the Title and Keyword term for the following search keywords : (“Intelligent Tutoring OR Adaptive Learning”) AND Systems AND “Characteristics” AND (“Applications OR Systems”).

This Systematic Literature Review approach was applying the inclusion and exclusion criterias to select the primary studies. Inclusion criteria was used to filter the studies that appropriate with research question. The exclusion criteria was used to clarify the validation of

literature study. These criterias are shown in table 1.

TABLE I. INCLUSION AND EXCLUSION CRITERIA

Inclusion Criteria	Exclusion Criteria
Educational Research	Publication date before 2005
Studies had to explain the characteristics or application of ITS	Duplicate paper of the same study
Publication year is 2005-2020	Studies was not written in English
Peer reviewed scientific articles	
Studies was written in English	

C. Data Extractions

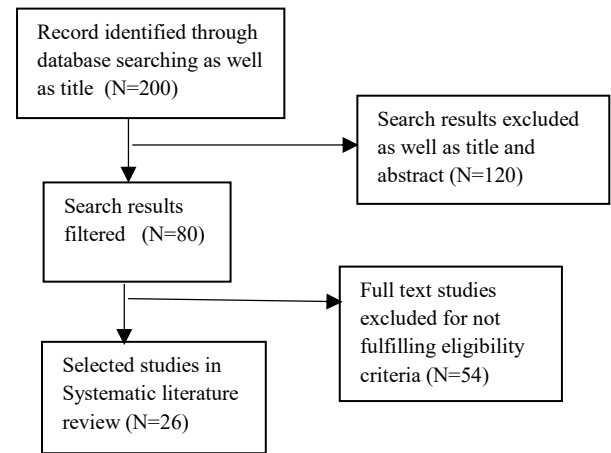


Fig.1. Flowchart of characteristics and applications of ITS selection

Process flow selection of studies can be found on Fig. 1. This research completing the data extractions into 3 steps, firstly studies have been founded from source publication relevant to the specified keyword defined as studies found. Secondly, filtering the studies based on the title and abstract in Studies Found which are a match to define the research question and complimentary defined as candidate studies. The third step is screening the studies in Candidate Studies which are all of the candidate articles will be read thoroughly to answer the research question as selected studies.

The first searches yielded 200 results based on related keyword, we first filtered out references that were not peer-reviewed scientific articles (book chapters, summaries of proceedings) as well as non-English language articles and duplicates. There are 80 papers which being to be candidate studies according to the relevant title and abstract to the research question. A total of 26 articles remained for this review. The summarized of the search results of each databases can be seen on table 2.

TABLE II. DATA EXTRACTION IN INCLUSION CRITERIA

Source	Studies Found	Candidate Studies	Selected Studies
ACM Digitaly Library	15	5	2
IEEEExplore Digital Library	41	15	7
Science Direct	62	35	7
Springer	25	3	3
Google Scholar	25	13	4
Scopus	32	9	3
Total	200	80	26

IV. RESULT AND DISCUSSION

Of the 26 studies on ITS that were analyzed, the results can be seen in Table 3 presenting general information about each study including the name of the system, references, and types of paper. Table 4 provides a summary of the main characteristics of each study.

TABLE III. DATA EXTRACTION FORM

ITS Name	Ref	Year	Article Type
CTAT	[16]	2009	Journal
IT2FLS	[17]	2016	Journal
ABDULLAH	[18]	2015	Conference
SAM	[19]	2017	Journal
AIED	[20]	2016	Journal
ITS-Proletool 3.0	[21]	2021	Journal
OWL	[22]	2020	Journal
TECH8	[23]	2015	Journal
GURU	[24]	2012	Journal
ASM	[25]	2018	Journal
FITS	[26]	2016	Journal
ITSPOKE	[27]	2006	Journal
AGT	[28]	2016	Journal
NORMIT	[29]	2005	Conference
CRITS	[30]	2015	Journal
TCP	[31]	2015	Journal
ITSB	[32]	2017	Journal
ADP	[33]	2016	Journal
AH-AITS	[34]	2010	Conference
LM	[35]	2015	Conference
VCASET	[36]	2016	Conference
TEX-Sys	[37]	2008	Journal
iTUTOR	[38]	2018	Journal
MyST	[39]	2011	Journal
SQL Tutor	[40]	2017	Journal
LANA	[41]	2019	Journal

A. RQ1 : Educational Fields of ITS

In the first research question, we tried to find the findings and analyze the application of ITS in various fields of education. To answer this question, we find three fields of education as shown in Fig. 2.

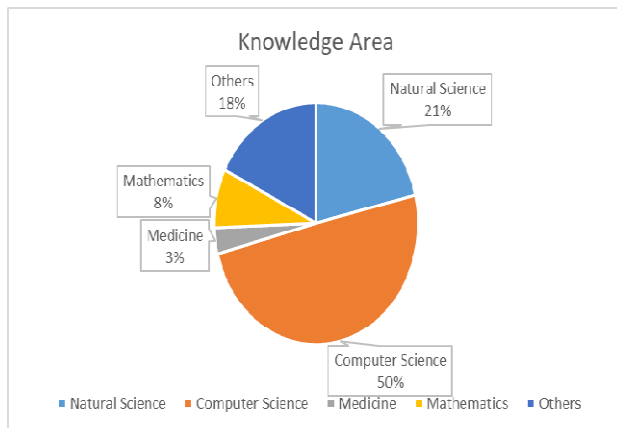


Fig. 2. Educational Fields Frequency

1. Knowledge Area

From in-depth identification of various ITS models, it

found that fields of science include natural science, computer science, medicine, mathematics, and others. From these findings, ITS was in the field computer science is the most prominent, followed by ITS natural sciences. Apart from being known for its field of knowledge, ITS also provides study guidance in various languages, for example, Arabic which is found in Abdullah and Lana, and of course in English which we most often encounter.

2. ITS Type

In this paper, we adopt 3 types of ITS as a central element in student modeling. The design of the model can be carried out with an adapted approach to the student object. As explained in [4]. Firstly, The example of Tracing Tutor (ETTs) is used to evaluate students' behavior which is adjusted flexibly and then compares it with students' behavior in solving problems. Model tutors have sophisticated step by step methods to identify complex problems and find the necessary strategies for students. ETT also attempts to maintain multiple interpretations of student behavior. Secondly, model-tracing tutors (MTTs), this ITS tracking student actions through the user interface in order to monitor student learning progress. To make this happen, ITS uses dialogue to help students solve problems. And the third is constraint-based modeling (CBM), in this model, ITS identifies the constraints encountered during the learning process, then creates a problem-solving model through knowledge-based modeling. So, to improve student knowledge, boundary violations must be identified that may occur during the learning process.

3. Educational Level

The third feature in this educational field is an important part of the first research question, here the implementation of ITS is initialized at a specific educational level. We identified the following 3 levels of education: primary school, middle school, college, and others. In this feature, it will be seen how the position of ITS at the college level.

B. RQ2 : AI Techniques

As shown in Table 4, ITSs used various AI techniques. Fig. 3 reported those techniques with their frequency (%) proved by those studies.

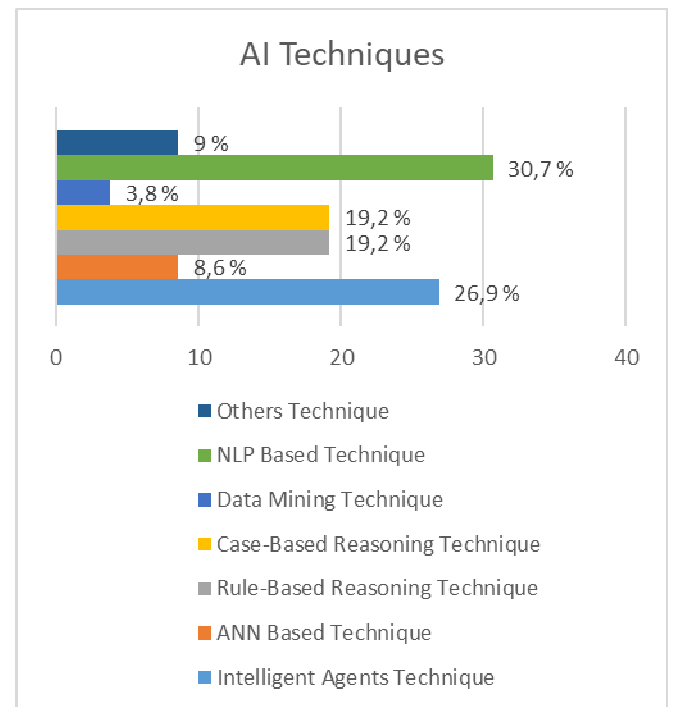


Fig. 3. Frequencies of used AI techniques in the ITSs.

NLP based techniques (30,7 %) and Intelligent agents techniques (26,9 %) were the most frequent AI techniques used for these ITSs. They were followed by the CBR and RBR (19,2 %), ANN based and others (8,6 %).

C. RQ3 : Characteristics of ITSs

ITS characteristics are made to show that the special characteristics of ITS are compared to other sciences. ITS characteristics are defined by 2 things, namely, understand

level and learner's characteristics.

1. Understand Level

For students, to facilitate the relationship between new knowledge and previous knowledge, an adaptive system is

TABLE IV. SUMMARY OF ITSs CHARACTERISTICS

ITS Name		LANA CITS	SQL Tutor	MYST	iTUTOR	Tex-Sys	VCASET	LM	AH-AITS	ADP	ITSB	TCP	CRITS	NORMIT	AGT	ITSPOKE	FIIS	ASMI	GURU	TECH8	OWL	ITS-Protool 3.0	AIED	SAM	ABDULLAH	IT2FLS	CTAT
Knowledge Area	Natural science			✓												✓			✓	✓	✓						✓
	Computer science	✓	✓		✓	✓		✓		✓	✓	✓	✓	✓	✓		✓	✓				✓				✓	
	Others								✓						✓									✓	✓		
	Medicine						✓																				
	Mathematics	✓								✓																✓	
ITS Type	Example-tracing tutors	✓	✓					✓			✓												✓	✓			✓
	Model-tracing tutors				✓	✓	✓		✓				✓		✓	✓		✓		✓	✓			✓	✓		
	Constraint-based tutors						✓							✓	✓		✓		✓			✓					
Artificial Intelligent (AI) Techniques																											
	Intelligent agents											✓	✓		✓					✓	✓						
	ANN based															✓		✓									
	Rule-based reasoning		✓										✓									✓					
	Case-based reasoning	✓												✓			✓						✓			✓	
	Datamining																				✓						
	NLP based				✓	✓				✓						✓	✓							✓	✓	✓	
	others								✓								✓										
Educational Level	College	✓	✓											✓	✓	✓	✓	✓	✓	✓		✓				✓	
	High school																						✓				
	Others																						✓				
	Elementary school				✓	✓	✓							✓						✓	✓			✓	✓		
Understand level	Explanation of concepts		✓										✓	✓	✓		✓									✓	✓
	Short answering questioning			✓																							
	Explanation of executed actions	✓			✓	✓	✓	✓	✓			✓	✓					✓	✓	✓						✓	
Learner characteristics	Cognitive factors			✓		✓	✓	✓	✓			✓		✓			✓					✓	✓				
	Learning performance/ style							✓				✓	✓		✓											✓	
	Knowledge level		✓									✓			✓										✓	✓	
	Behaviour in the learning path	✓	✓			✓		✓	✓					✓	✓		✓	✓				✓					
	Learning preferences		✓				✓						✓					✓									
	Others/ Affective factors				✓													✓	✓							✓	

needed. In this case, the communication system built has several objectives including helping students provide the right answers to the questions and explanations they pose; to correct in case of misperception, and summarizing the topics taught to make the main concepts clearer.

Within the group of systems at the understand level, explanations of concepts described in this subgroup are IT2FLS, FITS, AGT, NORMIT, CRITS, ITSB, ADP, LM, VCASET, Myst and SQL-TUTOR. These systems require students to provide answers in the form of detailed explanations to the questions given by the system. Because if students only give short answers it will result in superficial knowledge. In the Teacher system, ITS requires students to give short lectures which are the result of a summary of their knowledge, complete conceptual maps, and complete assignments. On Abdullah provided a feature to formulate questions with short answers to students, this was also found in Lana. From this research we found that the most communication's understand level is the explanation of executed action.

2. Learner's Characteristics

As represented in Table 4, an adaptive or customized learning was obtained in ITSs based on the several learners' characteristics, with Fig. 4 revealing these characteristics with their frequency in the papers.

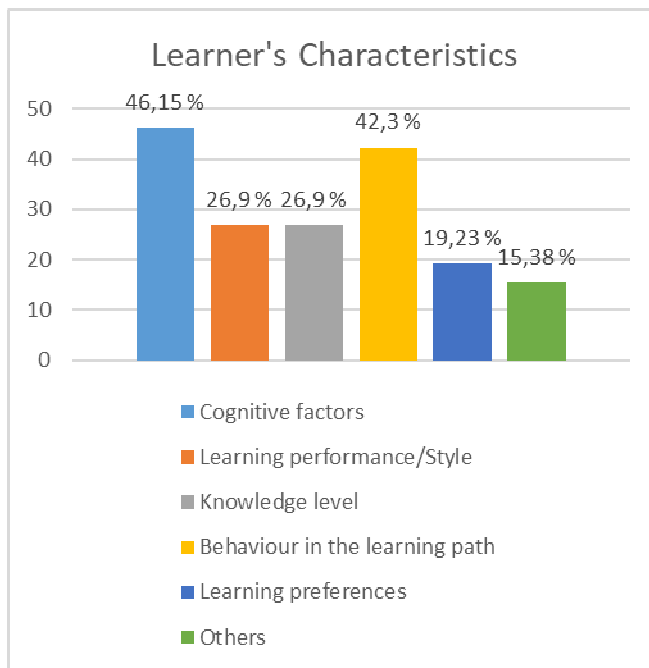


Fig. 4. Frequencies of learner's characteristics

The type of student modeling as seen in Fig. 4 is the main factor for classifying ITS types. Learning outcomes will not be the same if ITS is applied to education that has a different character. [4]. As we know, the characteristics of learning are developed in student modeling [42]. In this paper, the characteristics of students are defined as the cognitive abilities of students in understanding the learning process, for example, problem-solving knowledge, decision making, learning in teams, etc. From the explanation above, it can be concluded that cognitive factors (46.15%) and knowledge level (42.3%) are characteristics of students that are most widely applied to most ITS.

This study also found that the behavior of students in the learning process included interaction or feedback with the system. To improve adaptive learning, more information related to students is needed.

V. CONCLUSION

From this in-depth analysis on SLR, during the last fifteen years of ITS development, we have identified some valuable knowledge about ITS. Our aim is to determine the results of the empirical evaluation of research in the ITS field. Based on the review literature we encountered, This SLR selected 26 papers as the primary analysis. From the primary study, we analyzed it's based on the perspective of three research questions, namely the field of education, applied AI techniques, and student characteristics. These three things are the main factors in ITS that are examined in this paper.

An adaptive learning tool that has increased significantly is the use of ITS, its application can also be found in various fields of education. The characteristics of students and the level of knowledge are the goals of adaptive learning at ITS that have been successfully achieved. Although ITS can facilitate reasoning in the learning process, this system is rarely applied in experimental subjects including problem-solving and decision making. The most widely applied AI techniques at ITS are NLP and Intelligent Agents. Student-based methods are the main thing in ITS being evaluated.

In future work, we will explore the educational possibilities of platforms in the cloud training.

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