A Systematic Review of Domains, Techniques, Delivery Modes and Validation Methods for Intelligent Tutoring Systems

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Abstract—**An Intelligent Tutoring System (ITS) is a computer software that help students in learning educational or academics concepts in customized environment. ITSs are instructional systems that have capability to facilitate user by providing instantaneous feedback and instructions without any human intervention. The advancement of new technologies has integrated computer based learning with artificial intelligence methods with aim to develop better custom-made education systems that referred as ITS. One of the important factors that affect students learning process is self-learning; all students cannot have similar experience of learning scholastic concepts from same educational material. Because students have individual differences that make some topics difficult or easy to understand regarding taken subjects. These systems have capability to improve teaching and learning process in different educational domains while respecting individual learning needs. In this study an attempt is made to review the research in field of ITSs and highlight the educational areas or domains in which ITSs have been introduced. Techniques, delivering modes and evaluation methodologies that have been used in developed ITSs have also been discussed in this work. This work will be helpful for both academia and new comers in the field of ITSs to further strengthen basis of tutoring systems in educational domains.**

Keywords—*ITS; intelligent tutoring system; intelligent learning; adaptive learning; intelligent tutoring; ITS review*

I. INTRODUCTION

Information and communication technologies (ICT) have become necessary part of educational system in order to replace traditional teaching system with modern teaching system [1]. Modern information resources like hypermedia, multimedia, internet and intranet are contributed together to provide advanced learning pedagogies [2-4]. The new educational model is learner centered model in which flexibility is provided to learner to learn according to their ability and requirements in simple words this new model is oriented toward learner or student [5, 6]. To increase efficiency of these learning model factors like adaptability, interactivity, intelligence and dynamically generated web contents are added to these models that leads them towards development of intelligent tutoring system (ITS).

Many factors have been highlighted in previous studies that reflect importance of ITSs in educational domain, such as time limitations and individual meeting with students make it difficult for teacher for provide feedback to individual student in large class [7]. In private tutoring system, usually tutor provide help to student as much as he/she can but providing as many tutors to facilitate number of students is not feasible option from economic point of view [8]. ITSs are a solution that can solve these kind of problems in education. The most important feature of ITSs is their ability to customize instructional strategies and activities according to learner's requirements and characteristics [9, 10]. Many researchers contribute their efforts for refining student's ability to solve different problems in education [11-14]. The first ITS named SCHOLAR tutor was introduced in 1970 [15]. This system was developed to review student's knowledge about South America geography. SCHOLAR tutor began two way interaction with students by using facts of knowledge and semantic network of concepts to appraise student's knowledge in geography [16].

The traditional ITSs consist of four main modules i.e. expert module, student or learner module, pedagogical or tutor module and user interface module [17]. The expert module deals with domain knowledge that learner or student wants to learn [18]. The methods for problem solving and evaluating students activities in learning process are also considered in this module [19]. The student module completely depends on student attributes such as learning style, activities, behavior and knowledge deficiency. All relevant information about student is gathered and updated in system to refine learning process [20]. Additional information such as past learning experiences and learning preferences may also be stored in system to provide adaptability in teaching process [10].

The pedagogical module identifies students deficiencies in specific topic or subject based on learner module and focus on the strategies to provide best material that overcome the deficiencies of student in specific area or subject or topic [21]. The user interface module is communication part of the ITS it provides interaction facility between system and user [22]. The aim of present study is to review the developed ITSs across educational fields and gather comprehensive information about their development techniques, purpose, delivery modes and evaluation methods. This paper is organized as following; in section II methodology of review is presented, results are presented in section III. The answers of posed questions are discussed in sub sections of section III and work is concluded in section IV.

II. METHODOLOGY

One of the most common ways to evaluate and understand all available research literature related to specific research problem or question is systematic literature review. In literature, numbers of methodologies are available for systematic review. The methodology adopted for this systematic literature review was based on guidelines presented in [23]. The review process consists of three phases which contain ten sub activities. The details of activities conducted in these phases are shown in Fig. 1 and discussed under.

In first phase of review the following questions were posed:

Q1: What are the subjects or domains for which ITSs have been designed?

Q2: What types of techniques or tools have been used in development of ITSs?

Q3: What type of delivery modes have been used by developed ITSs?

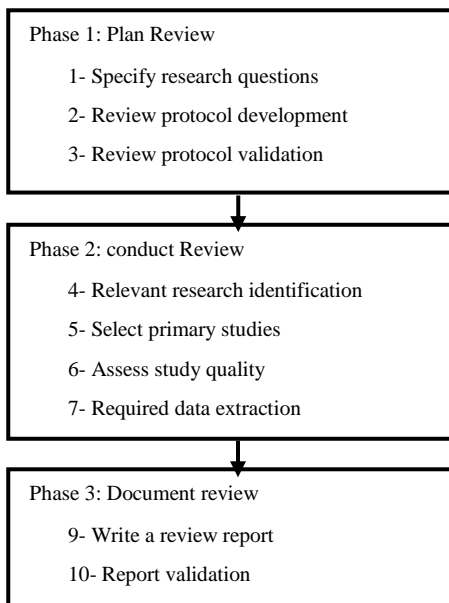Q4: How the techniques have been validated?

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│ Phase 1: Plan Review                     │
│                                          │
│   1- Specify research questions          │
│                                          │
│   2- Review protocol development         │
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│   3- Review protocol validation          │
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│ Phase 2: conduct Review                  │
│                                          │
│   4- Relevant research identification    │
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│   5- Select primary studies              │
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│   6- Assess study quality                │
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│   7- Required data extraction            │
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│ Phase 3: Document review                 │
│                                          │
│   9- Write a review report               │
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│   10- Report validation                  │
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Fig. 1. Review Process Adapted from [23].

TABLE I. REVIEW PROTOCOL

Year	Sources	Keywords
2014-2018	IEEE Xplore, science direct, google scholar, ACM portal digital library, springer	ITS, intelligent tutoring system, intelligent learning, adaptive learning, intelligent tutoring, ITS review

The questions were formulated in order to complete first sub activity of phase 1. In second sub activity of phase 1 a review protocol was developed. The review protocol includes considered time span of published papers, publication sources and keyword used to find required data. The research focus on the articles published in last five years and repositories used to find out required data include IEEE xplorer, science direct, ACM, Google scholar, springer and web of science. The final review protocol is given in Table I. The developed protocol is reviewed and validated after making some necessarily changes by researchers.

The execution of search chain on selected sources provides us a set of 82 articles. These articles were screened on basis of their title and abstract. After initial review according to inclusion criteria these 82 articles were filtered and only 39 articles were left that meet our inclusion criteria. For strengthen the search related to relevant articles, backward snowballing guidelines presented in [24] was also adopted to find out cited papers in selected articles that meet our inclusion criteria; this was done to make sure that no articles related to our research questions were left to considered.

In second phase of review a literature search was conducted in pre-defined databases by using keywords mention in Table I. These keywords were used in combination and alone for initial collection of research material related to our specified research questions. The inclusion criteria of this study is strictly based on posed research questions. Only those articles that contain material related to our research question were considered in this review.

III. RESULTS

The results of review are presented in this section. A year wise representation of results is given in Table II. These results are characterized with research questions posed earlier in this study. The variables of selected studies are presented in Table III.

A. What are the Subject/Domains for which ITSs have been Designed?

The result of review Table IV shows educational domains for which ITS have been designed. The frequency of each educational field in selected papers is demonstrated in Fig. 2. These domains were divided into six basic categories include; computer science, health/ medical science, mathematics, physics, language and others. Computer science was leading field in which ITS have been widely used to provide help in learning process. In computer science, programming was major area in which these systems were used. The frequency of systems that were designed for programming purposes in computer science domain was 61.11 %. Majority of the users of these systems were university level students.

TABLE II. YEAR WISE SEARCH RESULTS

year	No. of papers
2014	7
2015	8
2016	6
2017	8
2018	10
Total	39

TABLE III.   VARIABLES OF SELECTED PAPERS

Publication year	Title	domain	purpose	Technique/tools	Delivery mode	Validation
2018	[8]	computer science	Problem solving in computer programming	Bayesian network & multi agent system	Web based	Experimental study (comparison between groups)
2018	[25]	mathematics	Personalization algebra teaching	Cognitive Tutor Algebra (CTA), Rule based	Computer based (proprietary)application software	Experimental study
2018	[14]	mathematics	Modeling mathematics learning	ALEKS(Assessment and LEarning in Knowledge Spaces)	Web based	Observation study
2018	[26]	Others	Find metacognitive prompt in ITS	iSTART (Interactive Strategy Training for Active Reading and Thinking) , NLP	Web based	Experimental study (pretest and posttest)
2018	[27]	computer science	teaching programming	Bayesian Network	web based	Experimental study
2018	[28]	Computer science	Enhancing object oriented programing	Naive Bayes algorithm	Software prototyping	Simulated student model (prototype testing)
2018	[29]	Computer science	teaching programming language	ITSB tool (Delphi IDE)	Computer based application software	User feedback
2018	[30]	Computer science	Android application development	Rule based reasoning	Web based	Experimental study
2018	[31]	medical	Learning platform for Autism Spectrum Disorder childs	Chatbot using machine learning techniques (Convolution Neural Network)	Theoretical Framework	No validation
2018	[32]	Computer science	Solving multimedia problems	MyST (my science tutor), Intelligent multi agents	Web based	Experimental study
2017	[33]	Computer science	Self-learning in computer engineering	Artificial Neural Network based technique & Vortex Optimization Algorithm	Computer based application software	Experimental study & user feedback
2017	[34]	Others	Engineering students assessment	Open learning environment (StuDiAsE), fuzzy rule based system	Web based	Student diagnostic test
2017	[35]	Physics	Teaching basic electronics	Bayesian-based technique (Bayesian knowledge tracing)	Proposed model	No validation
2017	[36]	Computer science	Deductive logic	Bayesian-based & data mining (classification) techniques	Web based	Experimental study (learner performance)
2017	[37]	Computer science	fundamental computer programming	-	Theoretical framework	Experimental study (student response)
2017	[38]	medical	Cardio metabolic risk assessment	Artificial Neural Network	Web based	Experimental (Comparative analysis between two groups)
2017	[39]	mathematics	Provide support in basic mathematics learning	PGBM-COMPS tutor program, Rule based reasoning	Theoretical framework	Experimental (pretest–posttest comparison)
2017	[40]	Computer science	Teaching programming language	ITSB authoring tool (Delphi IDE)	Computer based application software	User feedback

Publication year	Title	domain	purpose	Technique/tools	Delivery mode	Validation
2016	[41]	medical	Cryosurgery prototype	Hybrid modeling approach (rules and constraints)	Computer based application software	Experimental (Comparative analysis between two groups)
2016	[42]	Computer science	Platform to teach MS word and PowerPoint	Type-2 fuzzy rule based reasoning	Web based	Student performance
2016	[43]	mathematics	Mathematical experiment	Bayesian technique	Web based	Experimental study (student performance on different conditions)
2016	[44]	medical	Understanding genetic breast cancer risk	Fuzzy-Trace Theory	Computer based application software (using Auto Tutor)	Experimental study
2016	[45]	Computer science	Problem solving (programming) by game base assessment	Bayesian network & multi agent system	Web based	Experimental study (controlled groups)
2016	[46]	language	Teaching English grammar	ITSB authoring tool (Delphi IDE)	Computer based application software	User feedback
2015	[12]	Computer science	Improve problem solving skills of novice programmer	Intelligent multi agent, Bayesian network and NLP algorithm	Web based	Learner knowledge (pretest and posttest) & performance
2015	[47]	medical	Human circulatory and emotional state	Meta Tutor (Intelligent multi agents)	web based	Correlation between emotional measurement methods
2015	[48]	Others	Multiple domain learning	Intelligent agents	Web based	Experimental study (student performance)
2015	[49]	Computer science	Slide presentation	Feature extraction & clustering, rule based reasoning	Web based	User feedback
2015	[50]	other	Cultural awareness Content delivery	Fuzzy rule based reasoning	prototype	User feedback
2015	[51]	language	Voice conversion in english	rule based reasoning	Web based	Experimental study (group experiment)
2015	[52]	Computer science	Basic computer skill improvement	Intelligent multi agents	Web based	Experimental study (learner knowledge and performance)
2015	[53]	Physics	Physics education	deep ANN & clustering analysis	framework	Comparison study
2014	[19]	Computer science	Debugging help for novice cs students	Case based reasoning	Computer based application software	Student performance (pretest and posttest) & log evaluation
2014	[54]	Physics	Automatic feedback in basic electronic	NLP based technique and rule based reasoning	Web based	User feedback & experiment (student performance)
2014	[55]	mathematics	Instructional method in mathematics	rule based reasoning	Computer based application software	Proto type testing, learner and teacher feedback
2014	[56]	mathematics	Peer tutoring in algebra	Bayesian knowledge tracing & rule based reasoning	Computer based application software	Student feedback & performance (pretest & posttest)

2014	[57]	Computer science	Analyze program in PHP	Bayesian-based technique	Computer based application software	Student feedback & performance (pretest & posttest)
2014	[58]	language	English language	UoLmP (rule based reasoning, if then rule)	Web based	User feedback
2014	[59]	Computer science	Controller programming	Case based reasoning	Computer based application software	Experiment (pretest & posttest)
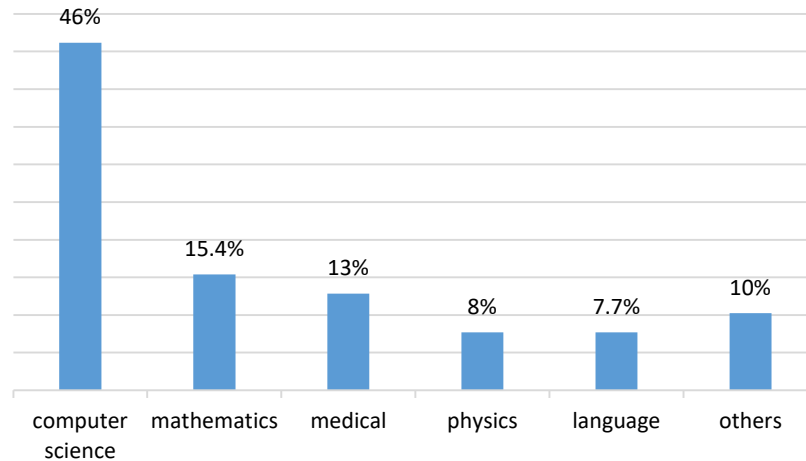
Fig. 2.   Frequency of educational field in ITSs.

TABLE IV.   CATEGORY WISE RESULTS OF QUESTION 1

Question	Category	No. of papers
What are the subject/ domains for which ITSs have been designed?	Computer Science	18
	medical	5
	mathematics	6
	physics	3
	language	3
	others	4

The second major field in which ITSs were used was mathematics, majority of ITSs (66.66%) were designed for school level students in this field to provide help in basic mathematics. The medical science field is at third rank, in which most of the system provides theoretical help to the students in understanding concepts about different topics, diseases and their management. In physics these systems were designed to provide theoretical concepts about different topics with focus on electronics. In languages domain all found ITSs were designed to teach English language or grammar.

B. What Type of Techniques or Tools have been used in Development of ITSs?

The review results of question 2 are presented in Table V and frequency of techniques used in development of tutoring systems is showed in Fig. 3. The techniques used for designing ITSs are categorized into eight different categories that are listed in Table V. Rule based reasoning technique was leading approach in designed ITSs. Rule based techniques increase trace of system reasoning for specific case with background familiarity [60]. This method was used in 28.21% studies to design ITSs, in computer science domain 66.66%

designed ITSs were based on rule based reasoning out of which most systems were designed for programming purpose. In mathematics domain 50% ITSs used rule based reasoning method for system designing. It seems that rule based method could be a suitable choice for decision making in computer programming fields and mathematics fields to deal with structure, patterns and numbers.

Bayesian technique was second widely used technique is designing of ITSs. These techniques based on probabilistic association between set of variables [61]. Bayesian method was used in 15.38% studies and majority of these studies were related to computer science, mathematics and physics domains. Bayesian technique is good method to deal with problems that deals with uncertainties [62]. In 12.28% studies intelligent agent systems were used in designed ITSs, intelligent agent system used to solve problems that are difficult to solve by an individual [63]. These systems were used for skill improvement, multi domain learning and problem solving in computer programming. In computing field intelligent agent techniques can be used to support its users in process of communication with system [64]. Frequency of data mining and Artificial Neural Network (ANN) techniques was almost similar.

Case based reasoning technique was least used technique in developed ITSs. This technique is usually used to solve new problems by finding most similar problem and updating the existing case according to found model [65]. However this technique was only used in two works that were related to computer programming. Case based reasoning can be beneficial in medical domain for design of tutoring systems [66].
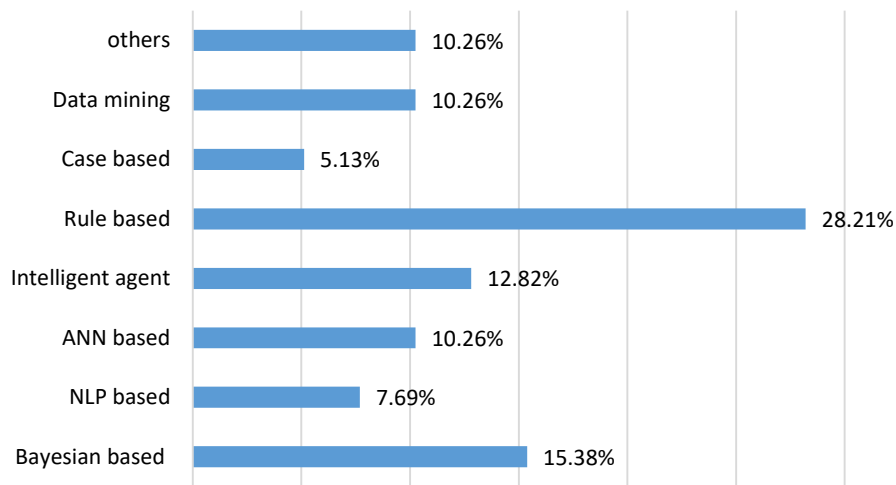
Fig. 3.   Frequency of ITSs Development Techniques.

TABLE V.   CATEGORY WISE RESULTS OF QUESTION 2

question	Techniques	No. of papers
What type of techniques or tools have been used in development of ITSs?	Bayesian based	6
	NLP based	3
	ANN based	4
	Intelligent agent	5
	Rule based	11
	Case based	2
	Data mining	4
	others	4

TABLE VI.   CATEGORY WISE RESULTS OF QUESTION 3

question	Delivery mode	No. of papers
What type of delivery modes have been used by developed ITS?	Web based systems	20
	computer based application software	12
	prototype	2
	proposed model	1
	framework	4

C. What Type of Delivery Modes has been used by Developed ITSs?

The results of question 3 are presented in Table VI and frequency of ITSs delivery modes is shown in Fig. 4. These results show that web based mode was leading mode in delivering by tutoring systems. 51% of selected papers were relied on web based systems for delivering educational material to learner. In computer science domain 55.55% intelligent tutoring systems were web based. The frequency of web based tutoring systems in mathematics and medical domains were 50% and 45%, respectively.

Computer based application software for intelligent tutoring was used in 30.77% studies. In mathematic domain 50% developed ITSs were computer based application software while frequency of application software in computer science and medical domain were 33.33% and 40%, respectively. In 10.26% studies researchers provides a conceptual or theoretical framework for tutoring systems. While model was proposed in only one study that was related to physics domain. These results reveal the fact that web based and computer application based modes are most popular infrastructure for the development of tutoring systems.

In our selected articles we do not found any ITSs which can provides mobile based content delivery to facilitate learner. However, mobile devices are considered as emerging technologies and its use in society is part of daily routine [67]. These devices can facilitate the implementation of tutoring systems independent of location and time [58].

D. How the Techniques have been Validated?

The results of question 4 are presented in Table VII and percentile results of question 4 are shown in Fig. 5. The method that was used widely for validation of the developed ITSs was experiment (59%). In experimental validation different type of techniques were used out of which 74% experiments were performed on basis of user or learner performance in which pretest and posttest were conducted to evaluate the system. 17% experiments were based on comparative analysis between groups of ITSs users and non-users, while remaining experimental approaches were based on learner knowledge and skills for system validation. Experimental methods were widely used in the field of computer science and medical. The frequency of these methods in computer science and medical were 61.11% and 60%, respectively.

In validation of any ITS, learner plays an important role, learner experience of using system or feedback is one of the most common method that could address the problems related to usability of specific system [68]. In this review we found only 15.38% studies in which systems were evaluated on basis of user feedback. While 10.25% studies use both experimental and feedback methods for system validation. The remaining validation method includes prototype testing, simulation and observation. Only one study in medical science domain was found in which not any kind of validation method was adopted for system evaluation.

TABLE VII.   CATEGORY WISE RESULT OF QUESTION 4

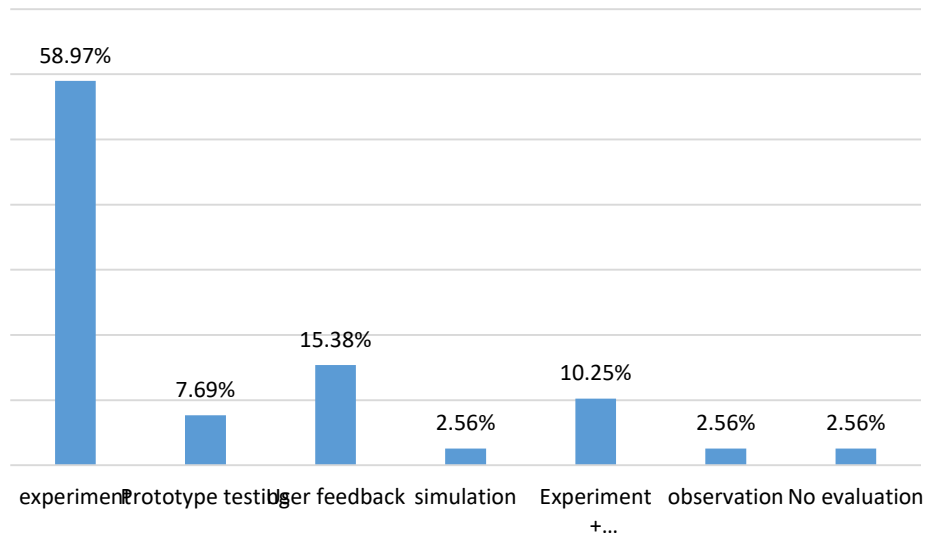| Question	Validation method	No. of paper
How the techniques have been validated?	experiment	23
	user feedback	6
	Experiment & user feedback	4
	Prototype testing	3
	simulation	1
	observation	1
	No. evaluation	1
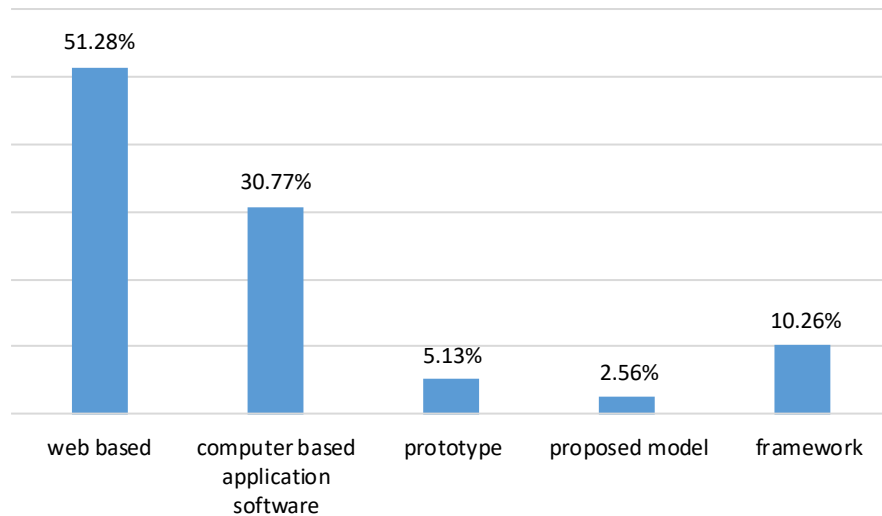
Fig. 4.   Frequency of ITSs Delivery Modes.

Fig. 5.   Methods of Evaluation in ITSs.

IV. CONCLUSIONS

Intelligent Tutoring Systems have capability to replace traditional teaching method with modern adaptive teaching method in which every student get knowledge according to his/her requirement. The main feature of these systems is their ability to customize instructional strategies and activities according to learner's requirements and characteristics. In this study ITSs educational domains, purpose of ITSs in specific domain, technique for ITSs development, delivery modes of ITSs and methods of validating designed ITSs were reviewed. Computer science was a major area in which these systems were used for teaching programming subjects. Rule based and Bayesian techniques were most frequent used techniques in design of ITSs and most of the developed systems provide web based services. In addition, learner performance was major method for validation of designed system. User feedback plays important role in evaluation of any system but we found that user feedback was not considered at high level in these studies for validation of ITSs. As use of mobile devices increase, these devices can facilitate learner in personalized learning in more customized way. We also observe in this study that none of system focus on mobile based tutoring, so on the basis of this study we recommended development of mobile based ITSs.

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