International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 1, January 2018, pp. 702–712, Article ID: IJCIET_09_01_068
Available online at http://http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=1
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

VALIDATION OF KNOWLEDGE BASED TUTORING SYSTEM DEVELOPED FOR TEACHING BASIC ENGINEERING DRAWING CONCEPTS

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ABSTRACT

Every group of learners is essentially heterogeneous with significant differences in their learning styles and preferences. Driven by the vast avenues thrown open by the technological innovations, strategy as well as technology of education are undergoing a sea change. These changes have given a fillip to the efforts to focus teaching to the requirements of individual learners using flexible approaches which cut across barriers of space, time, materials and media. Knowledge Based Tutoring System (KBTS) is a system aimed at customizing the learning experiences to suit the needs and learning preferences of the individual learners. Teaching learning is a complex process involving different entities. These entities are represented by different components of the KBTS. "Domain Knowledge Component" represents the Content area while "Student component" models the actual learner whereas "Pedagogy component" and "Control component" represent the strategy followed in the teaching learning process. "Engineering Drawing", popularly known as the "language of engineers" is a course offered in the first year of various Engineering Undergraduate Degree programs. Engineering drawing is the science of representing the real world objects which are in 3D through different views on paper which is essentially 2D. Such a representation requires a high level ability of visualizing the object in various orientations and positions. The paper discusses an approach adopted for developing a Knowledge Based Tutoring System for teaching the basic concepts of engineering drawing and validating it by adopting a single group pretest posttest experimental design. The analysis is presented using adopting appropriate statistical techniques.

Key words: Knowledge Based Tutoring System, Validation, Pre Test – Post Test experimental Design.

Cite this Article: Abdul Khader A.A and Brahadeeswaran D, Validation of Knowledge Based Tutoring System Developed for Teaching Basic Engineering Drawing Concepts. *International Journal of Civil Engineering and Technology,* 9(1), 2018, pp. 702-712.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=1

1. INTRODUCTION

Effective instructional delivery demands the adoption of appropriate tools of Educational Technology which focuses on designing suitable learning experiences keeping both objectives of teaching and abilities of individual learners in mind. The objective is to arrive at the best mode of instruction which will essentially involve presenting the learner with a set of planned learning experiences. In addition, it may involve modification of the learning environment by techniques of presentation or arrangement of learners' activities. The content will be a mixture of text, pictures, animation, audio and video depending on the nature of the educational objectives.

Engineering drawing is a course which forms an integral part of engineering programs offered by different universities. Various conventions and approaches are adopted to graphically represent real world objects through engineering drawing. This representation requires the ability to visualize the objects mentally in different positions so that its projections can be properly represented through different views in drawing. Many of the students find this visualization difficult and hence fail to properly understand the course and apply the knowledge to produce engineering drawings as per the prescribed standards. In engineering drawing, the objects are generally represented in related views such as "top view", "front view" and "side views". Reading and understanding an engineering drawing involves the ability to visualize the object by mentally coordinating different views of the object. Once proper visualization of the object is done, it can be represented on paper by manual drawing or by using a computer. Using computers to prepare the drawing lead to the change in the nomenclature of the course to "Computer Aided Engineering Drawing". Teaching the visualization skills to recognize real world 3D objects by their 2D drawings calls for sophisticated teaching strategies. For achieving this objective, a more user friendly approach of Knowledge Based Tutoring System (KBTS) is developed. The developed KBTS is validated by using an experimental design.

2. KBTS

The reach as well as processing abilities of computers have increased over the years coupled with more sophisticated and user friendly software which in turn enables the educators to develop a variety of learning resources to match the learning preference of individual learners. A student friendly adaptive system of education was proposed by Sleeman and Brown (1982) and the term used to represent the system was "Intelligent Tutoring System" (ITS) implying the ability of the system to adapt to the needs of the individual learners. A more elaborate and modular structure was proposed by Martha (1988) which was an attempt to model the different entities of teaching learning process. Knowledge Based Tutoring System (KBTS) was the word coined to represent this system. An approach to integrate this system with Artificial Intelligence was proposed by Wenger (1989)

2.1. KBTS as a suitable strategy for teaching Engineering Drawing

As visualizing the object in different positions and drawing its projections is the crux of the matter in Engineering, a Computer Aided Learning System can be more effectively used. A learner can view the object in virtual 3D space so that visualization becomes easy and comprehensive. Computer animations and graphics can be used to show the object in different positions. As the different concepts in Engineering Drawing are inter-related, proper understanding of the previous concepts may be essential for learning the subsequent concepts. Learners' mastery of the previous concepts must be measured and analyzed before presenting the subsequent concepts. In this direction, a Knowledge Based Tutoring System (KBTS) will be very appropriate. Hsieh (2014) used a KBTS for teaching ladder logic programming for Programmable logic controllers (PLC). The participant evaluation in the study indicated that after using the system, the users learned how to solve the problems and had a much better performance than before. Maaike Waalkens (2013) showed that an intelligent tutoring system enables the students to develop strategic flexibility to achieve desirable outcome in many domains. Ido Roll (2011) identified greater transferability of leaning to new domains after learning through Intelligent tutoring systems.

The KBTS will have a large database with respect to the content which will include text, graphics, animations, audio and video. The content appropriate for the learner will be selected from this database. The system will maintain a dynamic student model for each learner. Based on this model, the contents that are appropriate for that learner are drawn from the knowledge base and presented. In addition, the system will provide opportunities for exploration by the learner by allowing the learner to change the orientation of the objects and see the consequent modification in its projected views.

2.2. Modeling entities of Teaching learning process as components of KBTS

According to Burger and Desoai (1992), KBTS is a powerful instructional tool identified by the following components. These components can be mapped with the entities of the teaching learning process as follows.

Curriculum Content: The content matter of the course is represented by Domain Knowledge component of KBTS. This is also called "Expert Module" of the KBTS (Martha, 1988).

The Learner : The learner's role in the teaching learning process is modelled by Student component of the KBTS. This module analyses the entry behaviour as well as terminal behaviour of the student as it tracks his dynamic transformative behaviour during his progress through the course. Martha (Martha, 1988) calls this "Student Diagnostic Module".

Educational strategy : The educational strategy adopted is represented by the Pedagogy components of the KBTS. Pedagogical principles derived from learning theories and educational experiences are represented by this module. "Curriculum and Instructional Module" is the term used by Martha (1988) to refer to this component.

Coordinating and integrating learning experiences: This is achieved through a Control component. The control component incorporates the provision for a user friendly interface, tracking the progress through the course and identifying learning difficulties so as to plan further delivery of content. This component corresponds to the "Instructional Environment" according to Martha (1988).

The above components are in conformity with the requirements of an automatic tutoring system as suggested by Benedict (Benedict, D B, Rosemary. 2016), viz., Observation of expert teachers, following the principles of learning and empirical modeling of simulated student

Implementation of KBTS also involves proper integration of these components into appropriate modules. The structure of the KBTS developed is represented in the Figure 1.

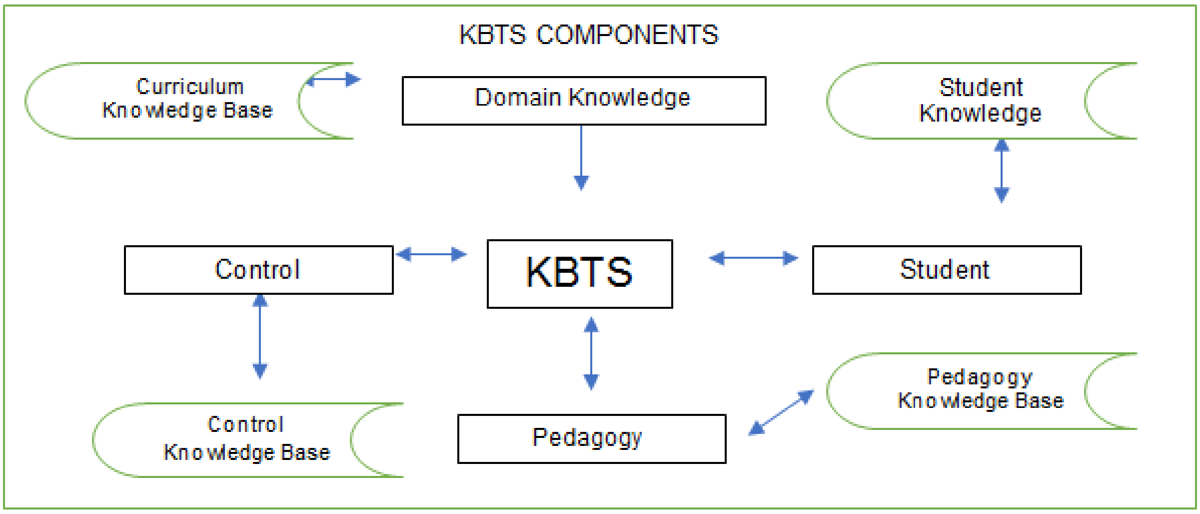

Figure 1 Framework for Developing KBTS on Engineering Drawing

3. METHODOLOGY

3.1. Survey to identify the difficult Concepts

Survey method was used to identify the concepts which are difficult to teach in conventional method. Engineering drawing is included in various engineering programs as a course in the first year. This is a unique course which aims at developing spacial visualization skills in the learners (Gordana M., Vladimir G. 2012). In order to identify the specific topics which are difficult to teach by conventional method, a survey was conducted for analyzing the content of the course. For this purpose, a questionnaire was administered to expert teachers having considerable experience in teaching the course. The topics for developing KBTS were selected based on the perception of the expert teachers about the difficulty level of each topic based on their experience in teaching the course in the previous years. The questionnaire was intended to elicit responses ranging from "very easy" (score of 1) to "very difficult" (score of 4). Three topics were selected for developing KBTS based on their difficulty level as shown in table 1.

Table 1 Ranking of topics based on their difficulty level

S. No	Topic	Average difficulty Level	Rank (based on difficulty level-descending)	Remark
1	Introduction to Computer Aided Sketching	1.429	8	
2	Principles of Orthographic projections	2.929	3	Selected
3	Orthographic Projection of Points	3.500	1	Selected
4	Orthographic Projection of straight lines	3.143	2	Selected
5	Orthographic Projection of Plane surfaces	2.214	7	
6	Projection of Solids	2.143	5	
7	Sections and development of lateral surfaces	2.857	4	
8	Isometric Projections	2.214	6	

3.2. Development of KBTS

The next step was to design a structure for developing KBTS and then developing the material of the KBTS as per the structure. This was accomplished in the following steps

3.2.1. Developing a modular structure for the content matter

The three identified topics were treated as three separate modules. For each of the modules, specific objectives were formulated. Under each specific objective, learning experiences in the form of teaching points were identified. The modular structure used for content development in terms of modules, objectives and teaching points is given below

Module 1: Basics of Orthographic Projection

Objective 1.1 : Explain principles of orthographic Projection

Teaching points

1.1.1 Concept of Projection

1.1.2 Effect of relative distances on projection

1.1.3 Orthographic projection system concept

1.1.4 Concept of 3 principal planes and principal views

I.1.5 Identifying the views

1.1.6 Formation of 4 quadrants by VP and HP

1.1.7 Summary of four quadrants

Objective 1.2 : Distinguish between first angle and third angle projection systems

Teaching points

1.2.1 First angle projection

1.2.2 system generating views

1.2.3 Third angle projection system generating views

1.2.4 Symbol for first angle projection System

1.2.5 Symbol for third angle projecting system

1.2.6 Comparison of first and third angle projection systems

Objective 1.3 : Draw orthographic views of simple objects

Teaching points

1.3.1 Six principal views in first angle projection

1.3.2 Six principal views in third angle projection

1.3.3 Analyzing the object to determine the minimum no of views required

1.3.4 Representing simple objects by their orthographic views

Module 2: Projection of points

Objective 2.1: Identify the quadrant in which points lie with reference to their positions relative to principal planes

Teaching Points

2.1.1 Case 1: Point lying in first quadrant

2.1.2 Case 2: Point lying in second quadrant

2.1.3 Case 3: Point lying in third quadrant

2.1.4 Case 4: Point lying in fourth quadrant

2.1.5 Inclusion of the profile plane

Objective 2.2 : Draw orthographic projection of points lying in various positions with respect to principal planes

Teaching Points

2.2.1 Examples of drawing projection of points

Module 3 : Projection of Lines

Objective 3.1 : Draw the projection of lines when it is parallel to at least one of the principal planes

Teaching Points

3.1.1 Case 1: Line lying on both VP and HP

3.1.2 Case 2: Line lying on HP and parallel to VP

3.1.3 Case 3: Line lying on VP and Parallel to HP

3.1.4 Case 4: Line parallel to both VP and HP

3.1.5 Case 4: Line Parallel to VP and Inclined to HP

3.1.6 Case 6: Line parallel to HP and inclined to VP

Objective 3.2 : Draw the projection of lines when it is inclined to all the principal planes

Teaching Points

3.2.1 Line Parallel to both VP and HP

3.2.2 Step by step procedure of drawing projections

3.2.3 Graded Exercises

3.3. Development of KBTS Material

The relevant learning material in the form of Knowledge Based Tutoring System was developed for the identified concepts as per the structure discussed above. The focus was more on graphical content, audio, video and animation as these elements can be suitably integrated into electronic media and enhance the effectiveness of learning (Cynthia, K L. 2008). These Multimedia elements are used as reusable resources in the instruction process. According to Zarko S., et. al. (2015), the use of variety of multimedia resources increases the interest value as well as the level of retention on the part of learners.

4. VALIDATION OF THE KBTS THROUGH EXPERIMENTAL METHOD

Single group pretest post test method was used for experimental validation of the KBTS. The experimental approach followed is described below

4.1. Sample

Engineering drawing is a common course for First Year Degree Program of various disciplines including Civil Engineering and Mechanical Engineering. For the study, a total of 60 first year Engineering Programs students of Civil Engineering and Mechanical Engineering programs were selected from 3 engineering colleges. In each of the college, 10 students each of Civil and Mechanical Engineering students were selected by random sampling. The composition of the sample is represented in Table 2

Table 2 Composition of the sample

	Civil Engineering Students	Mechanical Engineering Students	Total no of Students
College - 1	10	10	20
College - 2	10	10	20
College - 3	10	10	20
Total	30	30	60

4.2. Pre Test

Pre test items were designed based on the objectives selected for teaching through KBTS. Engineering drawing being a course offered in the first year of the program, questions were framed on the first three levels of Bloom's taxonomy (Bloom 1956), viz., Remembering, Understanding and Application. Different weightages were given to different levels of questions by assigning a score of 1 for Remembering level questions, a score of 2 for understanding level questions and a score of 3 for Application level questions. The distribution of questions with respect to the objectives and level of learning is given in table-2.

Table 3 Distribution of questions with respect to objectives and cognitive levels.

	Objective 1		Objective 2		Objective 3		Objective 4		Objective 5		Objective 1		Objective 6		Total	
	No of questions	Total Score	No of questions	Total Score	No of questions	Total Score	No of questions	Total Score	No of questions	Total Score	No of questions	Total Score	No of questions	Total Score	No of questions	Total Score
Remembering Level question	4	4	0	0	0	0	0	0	0	0	0	0	0	0	4	4
Understanding level questions	6	12	5	10	5	10	6	12	3	6	7	14	4	8	32	64
Application Level questions	0	0	0	0	1	4	1	3	5	15	0	0	4	12	14	42
Total	10	16	5	10	2	8	7	15	8	21	7	14	4	20	50	110

The validation of the test items was done through subject experts so as to remove any ambiguity or possible misunderstanding of the items on the part of the learners. Care was taken to have an even random distribution of keys and distractors in the items. To avoid the effect of guessing, negative marking system was adopted. For wrong answers, the student was given a negative score equal to ¼th of the score assigned to a particular question. As the full system is delivered online, the students were required to first register giving their demographic details. After registration, he/she can log into the system and will be first taken to the pre test consisting of the 50 questions. The system records his responses and stores his scores in the databases with respect to each of the item. The time taken for the student to complete the test is also automatically recorded. For convenient implementation of the system, the registration was done and pre test was administered on one day and the actual instructional delivery and post tests were done on the next day.

4.3. Instructional delivery through KBTS

Once the pre test is completed, the student is taken to the first module of the course. On completion of the first module, he/she is allowed to take the second module and on its completion, is allowed to take the third and final module. Interaction of the student with the system is recorded through feedback question and the remedial material is provided before the student proceeds to the next stage of learning. Typically, each module is designed such that an average student can complete the module in 45 minutes. A break of 15 minutes is provided in between so that the student can complete the three modules in 2¾ hours.

4.4. Post Test

The student was made to take the post test immediately after completion of the three modules of instruction. The post test is also designed on the same model of pre test with respect to the objectives and level of learning. However, parallel form of question items were used in the post test at about the same difficulty level.

5. RESULTS AND ANALYSIS

The comparison of pre-test and post-test were done for determining the enhancement of learning through the KBTS. This comparison was done with respect to various parameters including the modules, objectives and the abilities. Paired sample t test is used for comparing the scores of pre-test and post-test with respect to all these parameters.

5.1. Module-Wise Comparison

A comparison of pre-test and post-test is done with respect to the three modules of the course. Paired sample t test was used for the comparison. The following table shows the result of the comparison

Table 4 Module-wise comparison

		N	Mean	Std. Deviation	Paired Differences		t	df	P VALUE
					Mean Difference	Std. Deviation			
1	Module 1 : PRE-TEST	60	0.1708	6.50155	-27.0458	9.08254	-23.066	59	≤0.001
	Module 1 : POST-TEST	60	27.2167	9.69301					
2	Module 2 : PRE-TEST	60	-2.3375	5.74969	-18.75	9.02374	-16.095	59	≤0.001
	Module 2 : POST-TEST	60	16.4125	9.99012					
3	Module 3 : PRE-TEST	60	-3.6292	3.8805	-15.9333	10.20872	-12.09	59	≤0.001
	Module 3 : POST-TEST	60	12.3042	11.16034					

The following conclusions can be drawn from the data with respect to the module-wise comparison of the scores as presented in the table 4.

- On comparison of the mean values of Module 1 PRETEST and Module 1 POST-TEST, the mean values of Module 1 POST-TEST is higher with a difference of 27.04583 which is statistically significant with a p value of <0.001.
- On comparison of the mean values of Module 2 PRETEST and Module 2 POST-TEST the mean values of Module 2 POST-TEST is higher with a difference of 18.75 which is statistically significant with a p value of <0.001.
- On comparison of the mean values of Module 3 PRETEST and Module 3 POST-TEST the mean values of Module 3 POST-TEST is higher with a difference of 15.93333 which is statistically significant with a p value of <0.001
- The t values show a significant improvement in the performance of the students in post test in all the three modules.

5.2. Comparison of the performance with respect to objectives

The KBTS was designed with seven educational objectives spread across the three modules. The difference in the pretest and post test score was compared with respect to each of the seven objectives and the result is tabulated as shown in Table 5.

Table 5 Objective-wise comparison

		N	Mean	Std. Deviation	Paired Differences		t	df	P VALUE
					Mean Difference	Std. Deviation			
1	OBJECTIVE 1 PRETEST	60	-0.1	3.09531	-13.8542	3.70447	-28.969	59	≤0.001
	OBJECTIVE 1 POST-TEST	60	13.7542	3.05961					
2	OBJECTIVE 2 PRETEST	60	0.208	2.3958	-5.8333	2.7872	-16.212	59	≤0.001
	OBJECTIVE 2 POST-TEST	60	6.042	2.3057					
3	OBJECTIVE 3 PRETEST	60	0.0625	3.69397	-7.35833	5.94455	-9.588	59	≤0.001
	OBJECTIVE 3 POST-TEST	60	7.4208	6.13884					
4	OBJECTIVE 4 PRETEST	60	-0.8167	3.82644	-10.65	5.37595	-15.345	59	≤0.001
	OBJECTIVE 4 POST-TEST	60	9.8333	5.16111					
5	OBJECTIVE 5 PRETEST	60	-1.8333	3.85012	-9.55417	5.87891	-12.588	59	≤0.001
	OBJECTIVE 5 POST-TEST	60	7.7208	6.6059					
6	OBJECTIVE 6 PRETEST	60	-0.733	3.3338	-8.325	5.1976	-12.407	59	≤0.001
	OBJECTIVE 6 POST-TEST	60	7.592	5.7912					
7	OBJECTIVE 7 PRETEST	60	-2.8958	2.03377	-7.60833	6.55313	-8.993	59	≤0.001
	OBJECTIVE 7 POST-TEST	60	4.7125	6.7444					

Here also, the data shows a significant improvement in the post test with respect to all the seven instructional objectives.

5.3. Comparison of performance across the three cognitive levels

The questions were designed to test the remembering, understanding and application levels of cognitive abilities. The difference was tested across these three levels of Cognitive abilities. The following table shows the result of the comparison

Table 6 Comparison with respect to cognitive levels

		N	Mean	Std. Deviation	Paired Differences		t	df	P VALUE
					Mean Difference	Std. Deviation			
1	REMEBERING – Level Questions PRE-TEST	60	0.0833	1.22791	-4.8125	1.22701	-30.381	59	≤0.001
	REMEBERING – Level Questions POST-TEST	60	4.8958	0.41755					
2	UNDERSTANDING Level Questions : PRETEST	60	-1.192	8.2821	-39.875	13.68993	-22.562	59	≤0.001
	UNDERSTANDING Level Questions : POST-TEST	60	38.6833	14.96315					
3	APPLICATION Level Questions : PRETEST	60	-4.6875	4.65337	-17.0417	10.81824	-12.202	59	≤0.001
	APPLICATION Level Questions : POST-TEST	60	12.3542	11.80557					

The table shows a significant level of improvement in the achievement across the level of cognitive abilities, viz, Remembering, Understanding and Application level questions.

Considering the full test including all the modules, objectives and cognitive levels, i.e., on comparison of the mean values of TOTAL SCORE of PRE TEST and TOTAL SCORE of POST TEST, the mean values of TOTAL SCORE of POST TEST is higher with a difference of 61.72917 which is statistically significant with a p value of <0.001.

6. CONCLUSIONS

Education is a dynamically evolving branch of knowledge with a constant look out for ever expanding frontiers of knowledge as well as more effective tools for implementing the newly acquired knowledge. Consequently, there arises a need for testing the applicability and appropriateness of the acquired knowledge and the advanced skills with respect to their ability to promote effective learning. Validation of instructional strategies by gathering feedback and its analysis will lead to further refinement and redirection of the educational strategies. Knowledge Based Tutoring System is an attempt to simulate the different entities of teaching so as to present the learner with a set of planed learning experiences with the objective of arriving at the best mode of instruction. Development of such a system was attempted to teach basic principles of Engineering Drawing with emphasis on development of advanced visualization skills on the part of learners. The system was experimentally validated using a single group pre test post test experimental design. The analysis was done using paired sample t test which shows a significant enhancement in learning with respect to different modules, different objectives of instruction and different cognitive levels of learning. The analysis points to the effectiveness of the approach used for developing the Knowledge Based Tutoring System as represented by the significant gain in each of the modules as well as with respect to all the objectives of instruction and cognitive levels of learning.

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