Intelligent Content Sequencing Through Preferences and Feedback of Special Needs Learner

Ph.D. Synopsis

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ABSTRACT

Learning through technology possesses two main components: First, digital learning objects for learning and second, the order in which the learning objects are taken for learning. The general tutoring systems provides the learning content and the order in which they are delivered in a fit for all strategy. In the current scenario, with students with different learning capacities this strategy does not work. Hence, there is a need whereby the students can learn at their own pace and in the order in which they understand best. For this to happen, personalization of learning content and sequence is needed. This research mainly focuses on the later part, which is sequencing of the learning content. Many sequencing algorithms have been developed that provide methods for dynamic content sequencing, ant colony optimization method being one of them. Ant colony optimisation algorithm is an approach used for finding most appropriate and effective learning paths for learners. It is an efficient approach for self-organizing learning and assists in personalizing the learning requirements.

Education is one of the primary needs of every individual. This is equally true for special children who are not part of the regular teaching curriculum due to the difficulties they face. The special children are broadly classified into two categories:

1. *Physically challenged.*
2. *Mentally challenged.*

This work focuses on how the need for education for mentally challenged children can be met. Learning through technology is a knowledge management concept where the learning resources have to be presented in a clear and comprehensive manner to the learners. This paper presents a new approach for recommending suitable learning paths for special needs learners by applying artificial intelligence technique, Ant colony optimization algorithm. The study is carried out for Attention Deficit and Hyperactive Disorder (ADHD) and children facing Learning Disability (LD).

The research proposes a meta-heuristic approach for sequencing of learning objects in creating personalized learning sequences using modified Ant Colony Optimization algorithm. Learning paths are recommended to the learners, using learner's preference and personal traits. As the learner takes up learning contents, depending on the learner's performance on the fly, new learning sequences are generated and provided to the learners.

1. State of Art of the research topic:

The Educational needs of children have changed from time to time. In addition to regular classroom teaching activity, many other components have been added to make learning more effective, knowledge providing and fun-filled [1, 2, 3]. This has become possible due to learning technologies that have been actively incorporated in the teaching-learning process. With the advent of learning technologies, it has become possible for learners to learn anything, from anywhere and at anytime. Learning technologies include a wide spectrum of technologies that include computer aided programs, computer aided technologies, adaptive hypermedia and many such [3, 4, 5, 6]. Education through learning technologies have benefitted to the regular school goers, but here we pose a question, is learning technology equally beneficial to children suffering from various disabilities [7, 8, 9]? The answer to the question is yes [10, 11, 12, 13], learning technologies can definitely aid children suffering from disabilities. With this background let us also understand how learning takes place using learning technology. Generally, technology based learning comprises of two components: (i) creation of learning objects and the (ii) sequencing of these learning objects [14, 15, 16]. In a general scenario, the tutor/domain expert prepares the sequence in which the topic needs to be learnt. This is done by the expert through his/her past experience and expertise in the sequencing. Thus, there is little or no choice left with the learner for arranging the topics or taking learning objects of his/her interest. Thus, each student gets same sequence of objects for learning. Every special child has a different way and pace of learning. Also the way in which s/he communicates with the learning objects is different. It would be thus a better way to provide the sequence of the learning objects the way the students need to learn [18, 19]. Tools that address to specific learning requirement of the learners have been developed, where specific needs are taken care of [20, 2, 3] . Sequencing of learning objects is thus a very key area that needs to be addressed to quench the learning thirst. Many sequencing algorithms have been stated and implemented for solving this problem [18, 19, 20, 21, 22, 23, 24]. Ant colony optimization technique: a part of swarm optimization methodology is extensively used to solve the sequencing problems [21, 22, 23, 24, 25, 26]. Adaptive heuristic search is made so as to provide dynamic learning sequences [26, 27, 28, 29]. This dynamism in learning sequences is equally important in case of special needs learners, reason being, each child suffers from a special kind of a difficulty and hence this needs to be addressed. As ant colony optimization method is one of the best method suitable for sequencing problem, this work proposes a modified ant colony optimization algorithm for building personalized solutions for special need children.

2. Problem Definition:

Sequencing of learning content in an intelligent tutoring system is a challenging task when it comes to teaching-learning for special needs learners. The dynamism in choice of content depends on many parameters specific to these special children. Thus, the aim to generate individualized learning sequences for specially-abled learners by applying heuristic search through modified Ant colony optimization algorithm is a research problem which is discussed in this work.

3. Objectives of Research:

1) To understand the learning requirement of specially-abled children (mental faculty).
2) To recommend learning technologies as one of the assistive technologies for providing learning solutions.
3) To prepare individualized content sequencing of the learning objects to meet the individual requirements of the special learners.
4) Obtaining efficient learning paths being an NP-Hard problem, studying algorithms that provide solutions for these, Ant Colony Optimization algorithm being one such.
5) To mimic Ant Colony optimization algorithm, modifying it as per need, for intelligent generation of personalised sequencing of learning content required by the children.
6) To create a model which analyses the need of the special children, mentors, teachers, parents, psychologists, domain experts and all who are involved in the teaching-learning process for these children.

4. Scope of work

1) Learning Technologies/ assistive technologies assist the special children learn in effective manner.
2) Individual learning tools for SNLs have been developed to fulfil the learning requirements but none of them offer personalization of learning.
3) Learning using technology requires learning objects to be catered to the learners as per their requirement and their pace of learning, this sequencing is done majorly for normal children, the same can be developed for special children also.

4) Generating learning paths on the fly is combinatorial NP Hard problem which needs to be solved using artificial intelligence algorithms.
5) ACO algorithms work best for generating learning sequences on the basis of the probability obtained for searching of the next node.

5. Original Contribution By The Thesis

5.1 Research Methodology:

Any Intelligent tutoring system (ITS) has two major components: (i) Creation of digital content and (ii) Sequencing of the created digital learning content. This piece of work concentrates on the sequencing part of the digital learning content. Recent education systems have seen a great change in the way learning is imparted. Using learning technology for imparting education has become a part and parcel of today's education system. This is also equally true and beneficial for specially-abled children. The specially-abled children belong to a large spectrum such as attention deficit hyperactive disorder (ADHD), autism, learning disability (LD) and many such. These difficulties again have a range of intensity ranging from being mild to extreme. This work focuses mainly on children suffering from ADHD and LD. Thus sequencing of learning content becomes essentially an NP-Hard combinatorial problem that can be solved using algorithms that help in dynamic sequencing of the learning content. Ant colony optimization algorithm is one such technique that is best suited for solving such problems. Although, many ITS use ACO for sequencing of learning objects, this has not been applied for special needs children. This work discusses how modified ACO can be of help for generating dynamic and intelligent learning sequences for specially-abled children.

A graph based approach is followed to find efficient learning paths for the specially-abled children.

5.2 Content and its Classification:

The learning content follows the hierarchy given below:

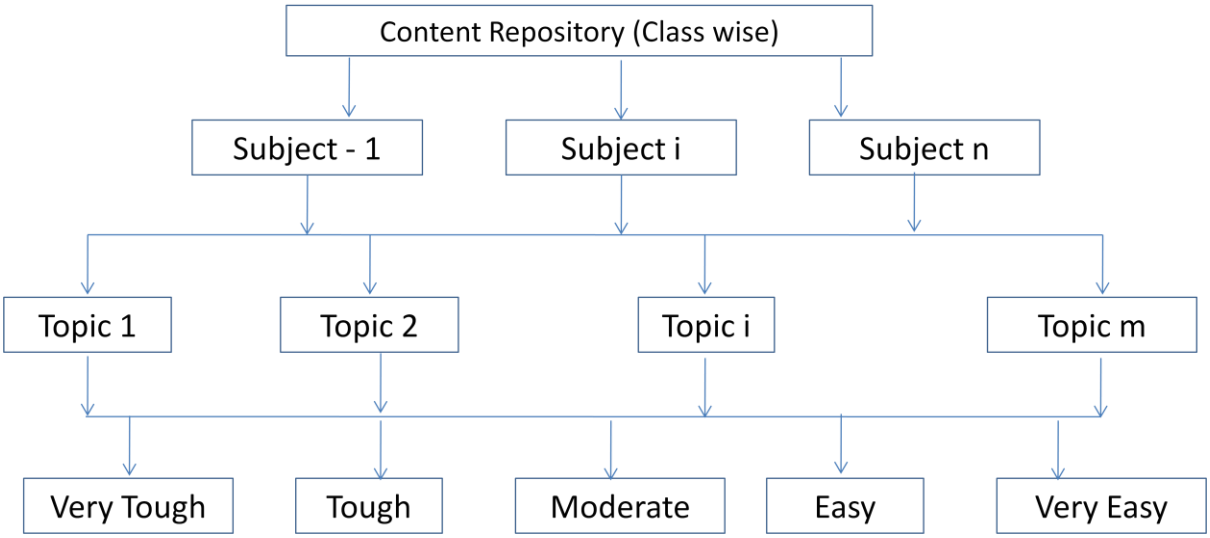


Figure 1: Hierarchy of content maintained for learning purpose.

5.3 Special Needs Learners Classification:

Along with the values of the learning content, the preference of the student is taken in terms of the difficulty the student is facing and intensity of the difficulty. The classification of difficulty and its intensity is given below:

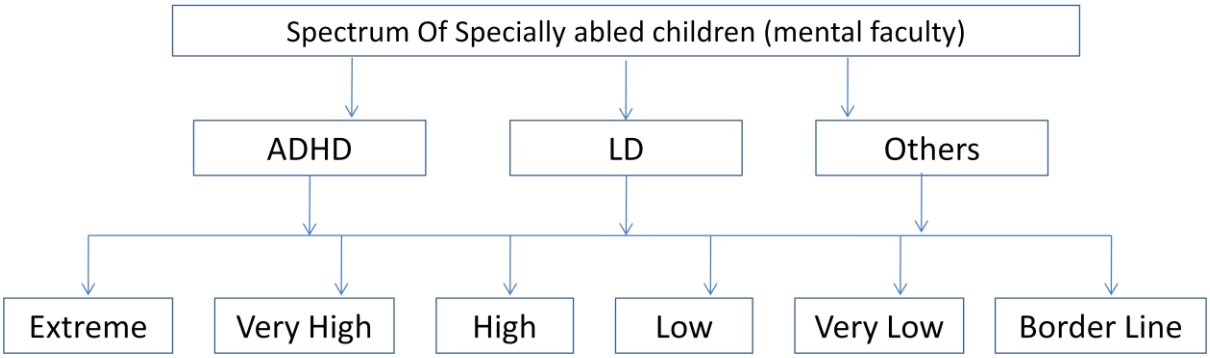


Figure 2: Classification of specially-abled children according to their difficulty and intensity

5.4 Model and its components:

ADHD: Attention Deficit and Hyperactive Disorder

LD: Learning Disability

In the graph-based approach, the nodes are considered to be the topics to be learnt by the students in a particular subject for a particular course. The nodes (topics) to be traversed

are either parallel or can be traversed in a particular sequence. In a regular teaching-learning process, this sequence of learning objects is decided by the teacher/domain expert/psychologist/psychiatrist or a mentor (hence forth will be referred as experts). Looking to the preferences and the background these children, no, one kind of sequence will work for all. Thus, the experts, through system will recommend individual sequences to be taken by the learner for learning purpose, but the choice of learning of the topic remains with the student. Once the student makes a choice for a topic to be learnt, the next node is available only when the student achieves a minimum of threshold value for the traversal. In the general ACO, ants drop pheromone (a chemical) which helps other ants to traverse the same path for finding the food easily and possibly the shortest path. Here the values for traversing are maintained in terms of the background of the learner, log of activities performed by the learner, assessment results of the learner and the recommendations made for the learner.

The meta-heuristics method for selecting the next node in the graph based search helps in generating the solution for efficient learning of specially-abled children. The architecture below shows the interactions of learner with other modules. It also shows the content repository, the set of rules governing the sequencing, data stores that store the learner activity and maintains the log, other details stored for further processing.

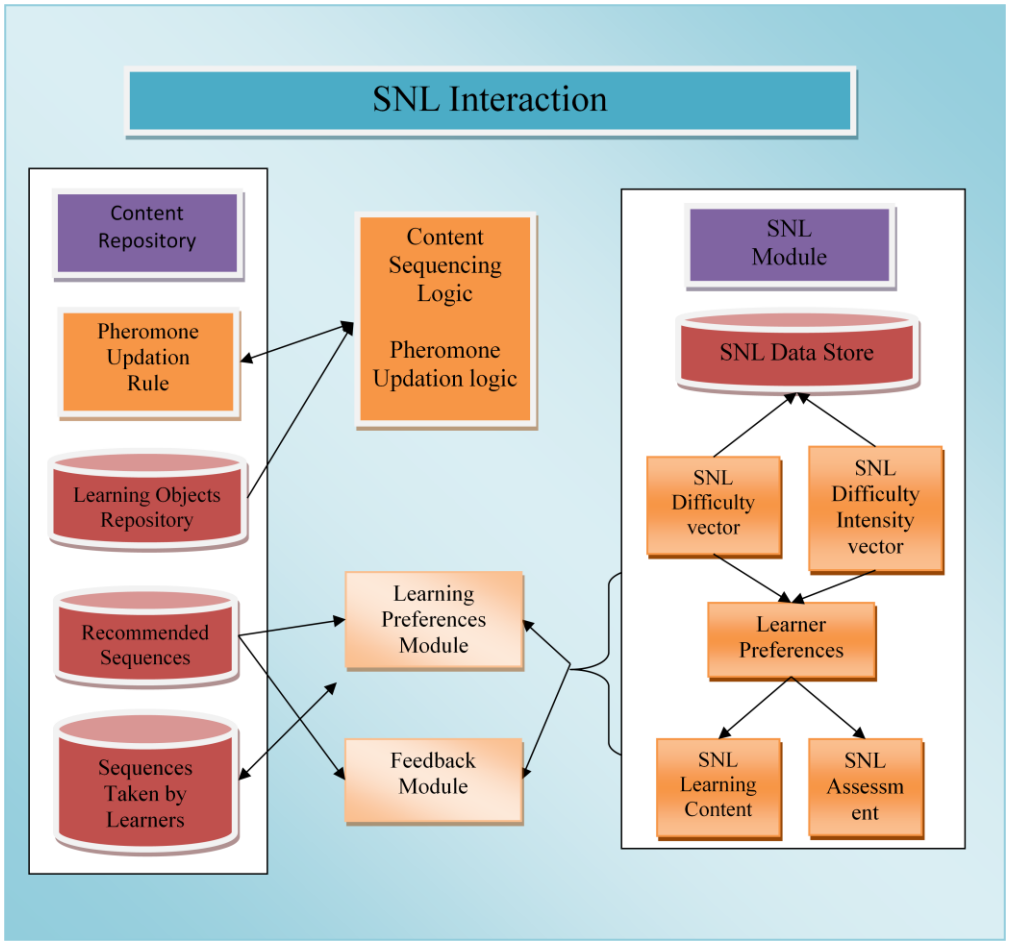


Figure 3: Architecture showing the interconnections between the content, learners and various components.

A learning sequence is a collection of inter-related concepts / topics, that are arranged in a particular order. The order is mentioned here in the form of a graph arrangement. In this graph structure, topics are represented as nodes and the rules for transition are the edge values. These edge values decide the next topic to be taken in the learning sequence. Each special needs learner (SNL), passes through the nodes and iteratively constructs sets of feasible solution. Every child thus, constructs his/her own solution for learning purpose. Each SNL makes a choice to traverse an edge (i, j) constructed between node i and node j by applying state transition rule. The decision of SNL_k moving from node i to node j is evaluated as the probability $P_k(i,j)$. This probability depends on the following factors:

- Performance of the SNL
- Learning ability of the SNL
- Time taken by the SNL to learn the given concept
- Whether the SNL has taken the recommended path or path of his/her own choice

- Successful completion of the concept taken by the SNL.

The learning takes place in the form of learning scenarios. The components of the learning scenario are proposed as follows: The learning scenarios are predefined sequences of concepts. The sequence of concepts is decided by the domain experts who decide and design the curriculum for SNLs. Thus, the learning scenarios should be designed as per the recommendations of these experts. Also within the curriculum, as the learning progresses, the concept difficulty level increases. Every concept, needs to be mapped with the level of difficulty apart from its position in the recommendation. We represent each learning scenario as a set of learning concepts LC = $\{LC_1, LC_2, .. , LC_x\}$. Each concept is given a priority that is decided by the domain expert/counsellor. The priorities are denoted as P = $\{P_1, P_2, .. ,P_x\}$. Furthermore, each concept is divided into various contents as LC = $\{LC_{11}, LC_{12}, LC_{13},...,LC_{1k}, LC_{21}, LC_{22}, LC_{23},..., LC_{2k}, LC_{x1}, LC_{x2}, LC_{x3},...,LC_{xk}\}$. Further, each content is associated with a difficulty level as D = $\{D_1, D_2, D_3, D_4, D_5\}$ as {very easy, easy, average, hard, very hard}. We maintain this so that it can be mapped with the disability spectrum of the SNLs. For example, if a child is cognitively weak, then a content that is of very basic level could be given, whereas if the SNL is at par with cognitive then, an advanced level of content can be given. Needless to say the difficulty level of the content is also decided by the experts/counsellors. The concepts are given an initial sequencing as per the curriculum. The contents residing in the concept have two parts: learning-practice part and assessment part. The SNL, depending on the difficulty faced and the intensity of the difficulty faced a particular content is recommended as a part of its learning. The SNL can take either the recommended path or a path of his/her own choice for learning purpose. An assessment matrix is made available as a reference with values for comparison to move to the next node.

Thus, for the learning scenario following terms are:

C = $\{C_1, C_2, .. , C_x\}$ for a learning scenario, the concepts placed in a sequence

P = $\{p_1, p_2, .. ,p_x\}$ priority attached with each concept

LC = $\{C_{11}, C_{12}, C_{13},...,C_{1k},C_{21}, C_{22}, C_{23},...,C_{2k}, C_{x1}, C_{x2}, C_{x3},...,C_{xk}\}$ Contents provided within a concept for a given learning scenario.

D = $\{d_1, d_2, d_3, d_4, d_5\}$: {very easy, easy, average, hard, very hard} A difficulty level attached with each content.

T = $\{t_{11}, t_{12}, t_{13},...,t_{1k},t_{21}, t_{22}, t_{23},...,t_{2k}, t_{x1}, t_{x2}, t_{x3},...,t_{xk}\}$ the threshold value for the SNL to move from one content to the other for a given learning scenario.

The following details of the SNL is maintained:

Each Special Needs Learner (SNL) has a profile that consists of the various details related to the SNL. This profile is maintained for mapping purpose of the content with the SNL. Following details of the SNL are maintained in two phases:

A: Learner's difficulty data: This value does not change throughout the learning phase of the SNL as this value is decided by the psychologist or psychiatrist. Thus, no modification is done to this value ever.

Learner's difficulty: Here the difficulty faced by the learner is stored. As mentioned earlier, Attention deficit hyperactive disorder (ADHD), Learning Disability (LD) and a combination of the two are considered. It is also possible that a child suffering from ADHD may also suffer from other difficulty.

Difficulty intensity: The learner's disability intensity is maintained. This is a spectrum of various qualitative values ranging from extreme to low. Categories of the difficulty intensity are as follows: {border line, low, moderate, high, extreme}

B: Activity log of the SNL: This value is maintained by the system when the SNL interacts with the system. A log of various activities carried out by the SNL is maintained so as to provide a personalized learning environment. The log maintains the following data:

Recommended Learning Paths: stores the contents that are recommended to the SNL by the system.
Actual_Path_taken: stores the actual path taken by the SNL during a learning scenario.
Attention_Span: This factor is stored in terms of the time taken by the SNL for completion of a particular task.
Interest_ in_Activity: This factor stores whether the SNL is interested in a particular activity or not. A value in terms of yes/no is considered for processing purpose. In order to find out the interest value, a threshold time is considered, if the time value is within the specified range we get the answer yes else a no is stored.
Completion_of_Task: This is Boolean value and a comparison with a standard value fetches a yes/no value for the SNL.

Concentration_during_the_activity: This value is taken as the number of times the SNL has take up a particular activity and in what time s/he has completed it. Since SNLs generally struggle with concentration, various turns are provided for a particular learning object to be learnt.

Assessment_results: The assessment results are maintained content wise separately and are tabulated for further processing.

Learning_path_info: Information regarding every concept learnt by the SNL is stored here.

Updation_in_Intensity_of_Pheromone: stores the change in the pheromone value on the edge connecting two nodes i and j while while transition of each SNL from *ci* to c*j*.

Other parameters also work in collaboration with the above such as: Remembrance, following of instruction, patience, processing of information, self-control and many such, but only the above parameters have been considered in this research.

ACO to Learning Scenarios

Ant Colony Optimization algorithm has the following two main components:

(i) Heuristic search:

The SNL starts with an initial learning content and moves further to add more contents to its learning path. The learning scenarios are perceived as nodes of a graph and the transition from one $node_i$ to $node_j$ is considered as the edge *(i, j)*. The transition takes place only when the calculated value for the edge is greater than the prescribed value. The SNL starts learning the contents of the concepts one after the other as per recommendations suggested by the system. If the SNL is able to perform at par as per the recommended performance, the current node is added to the SNL's learning path and the SNL moves to the next node. Also the intensity of the recommendation for the current content increases and gets updated. In case, the performance is not as per expectation, the SNL is recommended a content with lower difficulty value and the intensity of the recommended node decreases as per the rules of updation. These modified values affect the further recommendations in the system.

(ii) Pheromone trail intensity:

The pheromone intensity over an edge *(i, j)* gets updated on the basis of:

1) The performance of the SNL in the context of assessment results
2) Number of times contents taken for learning
3) Time taken for completion of a content
4) Time taken for completion of a concept

5) Other SNL details from the activity log.

6. Experiment and Results:

The research discussed in this work uses experimentation methodology. Although many students were considered during the initial phases of experimentation, later on a class of 18 students was considered with ADHD and LD as per the difficulty and the intensity of difficulty the students faced. With the inputs of classes such as Nursery, Junior and Senior, with basic subjects such as Maths, Language skills, General Science and General Knowledge, learning content with recommended paths was provided to the learners. For result purpose, ADHD children with extreme intensity of Nursery class with Maths as a subject were considered. Various learning contents with different difficulty levels were provided for learning. Table – 1 shows the various contents that were recommended to the learners. This content was further sequenced as per the learner preference, difficulty faced, intensity and other parameters related to the learner.

Content ID	Content Path
101	C:\Program Files\ContentVideos\Nursery\Maths\Learning-Numbers-1-20.mp4
102	C:\Program Files\ContentVideos\Nursery\Maths\NurseryNumbers1 to 10.mp4
103	C:\Program Files\ContentVideos\Nursery\Maths\NumberSong.mp4
104	C:\Program Files\ContentVideos\Nursery\Maths\SimpleCounting-1-20-3.mp4
105	C:\Program Files\ContentVideos\Nursery\Maths\SimpleCounting-1-20-3.mp4
106	C:\Program Files\ContentVideos\Nursery\Maths\SimpleCounting-1-20-3.mp4
107	C:\Program Files\ContentVideos\Nursery\Maths\SimpleCounting-1-20-3.mp4
201	C:\Program Files\ContentVideos\Nursery\Maths\Counting1_5_1.mp4
202	C:\Program Files\ContentVideos\Nursery\Maths\Counting1_5_2.mp4
203	C:\Program Files\ContentVideos\Nursery\Maths\Counting1_5_3.mp4
204	C:\Program Files\ContentVideos\Nursery\Maths\Counting1_5_4.mp4
205	C:\Program Files\ContentVideos\Nursery\Maths\Counting1_5_5.mp4
206	C:\Program Files\ContentVideos\Nursery\Maths\Counting6_10_1.mp4
207	C:\Program Files\ContentVideos\Nursery\Maths\Counting6_10_2.mp4
208	C:\Program Files\ContentVideos\Nursery\Maths\Counting6_10_3.mp4
209	C:\Program Files\ContentVideos\Nursery\Maths\Counting6_10_4.mp4
210	C:\Program Files\ContentVideos\Nursery\Maths\Counting6_10_5.mp4
211	C:\Program Files\ContentVideos\Nursery\Maths\Ordinal1.mp4
212	C:\Program Files\ContentVideos\Nursery\Maths\Ordinal2.mp4
213	C:\Program Files\ContentVideos\Nursery\Maths\Ordinal3.mp4
214	C:\Program Files\ContentVideos\Nursery\Maths\Ordinal4.mp4
215	C:\Program Files\ContentVideos\Nursery\Maths\Ordinal5.mp4
216	C:\Program Files\ContentVideos\Nursery\Maths\BigSmall1.mp4
217	C:\Program Files\ContentVideos\Nursery\Maths\BigSmall2.mp4
218	C:\Program Files\ContentVideos\Nursery\Maths\BigSmall3.mp4
219	C:\Program Files\ContentVideos\Nursery\Maths\BigSmall4.mp4
220	C:\Program Files\ContentVideos\Nursery\Maths\BigSmall5.mp4
221	C:\Program Files\ContentVideos\Nursery\Maths\Sorting1.mp4
222	C:\Program Files\ContentVideos\Nursery\Maths\Sorting2.mp4
223	C:\Program Files\ContentVideos\Nursery\Maths\Sorting3.mp4
224	C:\Program Files\ContentVideos\Nursery\Maths\Sorting4.mp4
225	C:\Program Files\ContentVideos\Nursery\Maths\Sorting5.mp4

Table – 1 List of content generated for learner with ADHD difficulty and Extreme Intensity.

The students were given five topics for learning; the recommended sequence is shown in the figure given below.

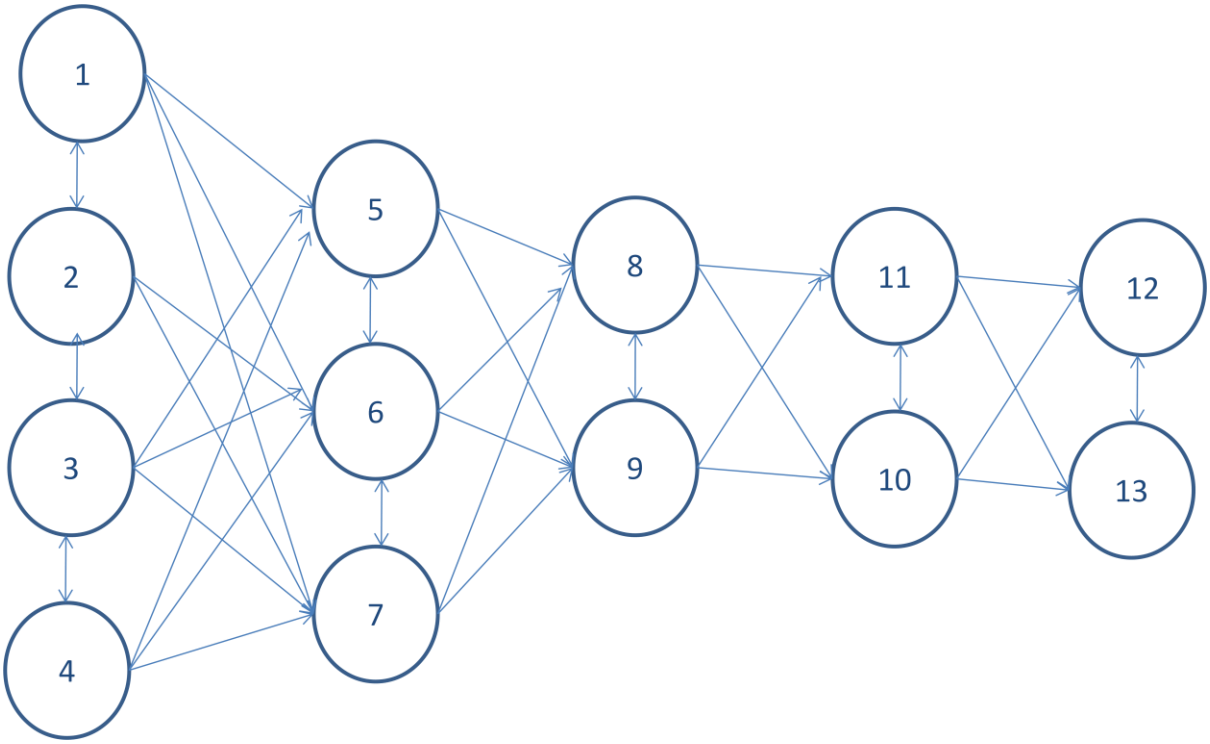


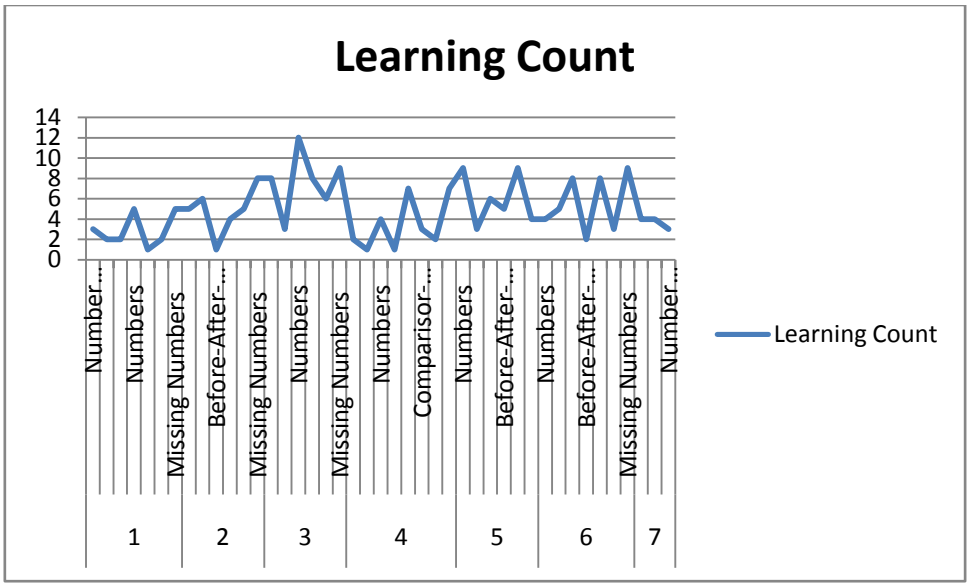
Figure 4 shows the sample sequence generated for the learners.

During the learning process, along with the preference and other details of the learner, the number of times the learner took for learning, number of times assessments taken and the assessment results were taken. These parameters act as input for further topic selection and the selection of the path to be traversed by the learner.

The learning count of the topics taken is given in the following table:

Number	Learning Content Name	Learning Count
	Number Recognition	3
	Number Sequencing (1-5)	2
	Comparison-Less than	2
	Numbers	5
	Before-After-Between	1
	Comparison-Greater than	2
1	Missing Numbers	5
	Numbers	5
	Number Sequencing (1-5)	6
	Before-After-Between	1
	Comparison-Greater than	4
	Comparison-Less than	5
2	Missing Numbers	8
	Number Sequencing (1-5)	8
	Before-After-Between	3
	Numbers	12
	Comparison-Greater than	8
	Comparison-Less than	6
3	Missing Numbers	9
	Before-After-Between	2
	Before-After-Between	1
	Numbers	4
	Before-After-Between	1
	Number Sequencing (1-5)	7
	Comparison-Greater than	3
	Comparison-Less than	2
4	Missing Numbers	7
	Numbers	9
	Number Recognition	3
	Number Sequencing (1-5)	6
	Before-After-Between	5
	Comparison-Greater than	9
5	Comparison-Less than	4
	Numbers	4
	Number Recognition	5
	Number Sequencing (1-5)	8
	Before-After-Between	2
	Comparison-Greater than	8
	Comparison-Less than	3
6	Missing Numbers	9
	Numbers	4
	Numbers	4
7	Number Sequencing (1-5)	3

The graph shows the learning content taken by the learners.

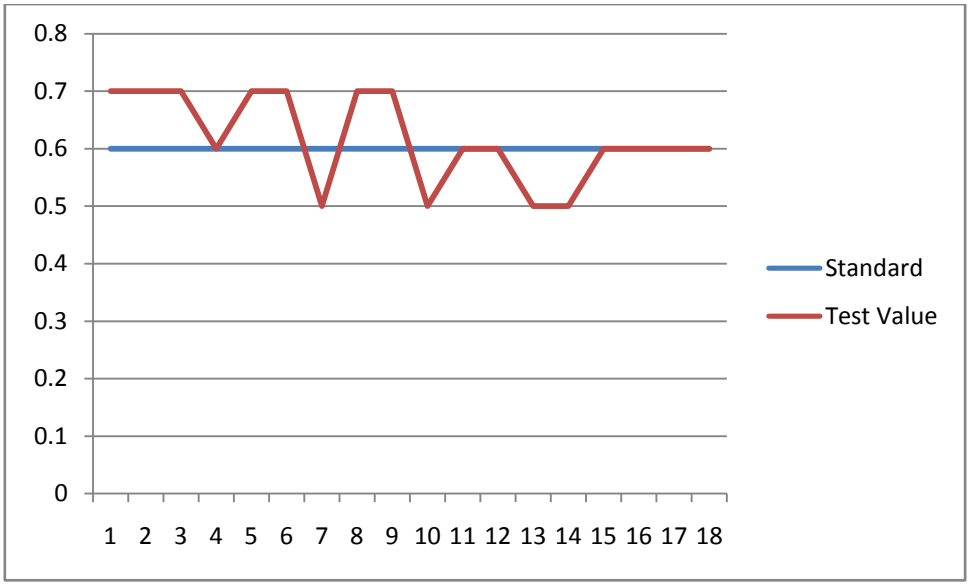


The results of the students were tabulated for the topics for learning. Following table, shows result of one topic along with the high/low values from the actual threshold set by the experts.

For first level, the threshold set was 0.6.

No.	Standard	Average of Assessments
1	0.6	0.7
2	0.6	0.7
3	0.6	0.7
4	0.6	0.6
5	0.6	0.7
6	0.6	0.7
7	0.6	0.5
8	0.6	0.7
9	0.6	0.7
10	0.6	0.5
11	0.6	0.6
12	0.6	0.6
13	0.6	0.5
14	0.6	0.5
15	0.6	0.6
16	0.6	0.6
17	0.6	0.6
18	0.6	0.6

Table – 3 Assessment results of the students along with the threshold value of 0.6



Inference: Out of the 18 students, who took up the learning through the model, four students could not perform up to the mark of the threshold, hence, were given for re-learning. Other students could go to the next topic since they could achieve the value equal to or greater than the threshold.

7. Contributions from research work:

1) Could understand the learning requirements of the special needs learners.
2) Could conclude that using learning technologies (specifically providing multimedia contents) enhances the learning process.
3) Able to generate and provide learning sequences on the fly to the special needs children.
4) Modified the heuristic approach by changing the parameters for obtaining the next content for learning.
5) Could propose a model for generating dynamically learning sequences.

8. Conclusion:

The work proposes personalized learning sequence generated for special needs learners using ACO algorithm. Using the personal difficulty details and the preferences of the SNLs, personalized learning sequences are recommended. The learner may take up the recommended path or can take a path of its own, in both the cases whatever learning takes place is maintained and used for further learning sequence generation. The learning

feedback is measured in terms of the performance during assessments carried out. Further, more parameters could be added for preference selection of learning paths.

9. List of all publications/presentations arising from the thesis:

- "A Survey on Effects of Computer Based technology for Special Needs Learners" - International Journal of Advanced Networking and Applications (Nov 2014)
- "Adaptive Learning model for ADHD and LD children: An Approach" - National Conference on Emerging Research Trends in Engineering, GVEC, Chandkheda, Gujarat (April 2016).
- "Improving Content Sequencing of Packaged Content through Feedback and Priority" - International Conference on Information and Communication Technology in Business, Industry and Government, Udaipur, Rajasthan, India (October 2016)
- "Multi-Agent simulation model for sequence generation for specially abled learners" - International Conference on Information and Communication Technology for Intelligent Systems Ahmedabad (March 2017)
- "Learning Needs for Special Needs Learners: A Graph based Adaptive Approach for Content Sequencing " 2017 International Conference on Soft Computing and its Engineering Applications (IEEE icSoftComp2017) (Dec-2017)

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