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The concept of personal learning pathway for Intelligent Tutoring System GeoMe

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Abstract

This paper presents a study of designing personal learning pathways for our intelligent tutoring system "GeoMe". The purpose of the study is to define specific requirements for our application and conceptualize the workflow for personal learning pathways.

Keywords: Learning pathway, intelligent tutoring system, space repetition, forgetting curve, Leitner system.

1 Introduction

Digital culture is increasingly applied in e-learning; it also contributes to improve the educational process by adapting to the student's interests, capabilities and knowledge. Nowadays there are many different kinds of educational software for students based on adaptive learning, personalized learning or even personal learning pathway (PLP). Learning pathway can be described as a route, taken by a pupil through a range of e-learning activities, which allows learners to get new skills and build knowledge progressively. Clement [1] defines a learning pathway as "The sequence of intermediate steps from preconceptions to target model form what Scott (1991) and Niedderer and Goldberg (1995) have called a learning pathway. For any particular topic, such a pathway would provide both a theory of instruction and a guideline for teachers and curriculum developers."

For students personal learning paths are the best solution, because they can more effectively acquire and retain knowledge and skills that

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will help them in real world. However, what about the elementary schoolchildren? For them it is harder to decide which learning model will be the most appropriate and effective. In this case, one of solutions can be designing an intelligent tutoring system (ITS) that will analyze the behavior and preferences of pupils and afterward will automatically recommend a personal learning pathway. So, in this paper we started with general description what ITS's are, followed by a short review of ITS "GeoMe"[2] and continued with philosophy behind of our personal learning pathway.

2 Intelligent Tutoring Systems

Intelligent Tutoring System is a part of a new breed of instructional computer programs with the aim to provide immediate support one-on-one and personalized feedback to learners. Canfield [3] defines ITS as a system that is able to diagnose and adapt to student's knowledge and skills. According to Daśić et al. [4] ITS intend to support and improve the teaching and learning process in a selected area of knowledge while respecting the individuality of a learner. Along the years, there are many definitions regarding what intelligent tutoring systems are, however, the common point is focused on using Artificial Intelligence (AI) techniques in order to track learner's needs and respond with an appropriate feedback.

Sleeman and Brown [5] coined the term "Intelligent Tutoring Systems" in 1982 in order to describe evolving tutoring systems and to distinguish them from the previous computer-aided instruction (CAI) systems. A little later, in 1988 the first conference dedicated to intelligent tutoring systems took place, where conceptions of ITS's were consolidated. However, the efforts in ITS first began with the development of what was called Intelligent Computer-Aided Instruction (ICAI) by Carbonell in 1970 [6], so he is called the *"father"* of intelligent systems for teaching and learning.

Carbonell's system was named SCHOLAR, whose goal was to communicate information regarding geography of South America to learners and to review their knowledge by maintaining a mixed-initiative dialogue with learners in a rather comfortable subset of English. It was

Carbonell's belief that the semantic net representation of the knowledge base used in this project was close to the internal knowledge structure of humans.

Research in AI and Cognitive Psychology fueled the new principles of intelligent tutoring systems. Thus, with time they evolved from very primitive form of ICAI into very progressive form, with significant development in their user interfaces. By using AI techniques, intelligent tutoring systems are now being used for a broad range of tasks, although, in a limited way.

For instance, some of the major tasks are: selecting appropriate teaching strategies; generating and solving problems; tracking learner's behaviour and progress; storing and retrieving data; recommending learning materials; diagnosing student's misconception; detecting learner's mood; offering immediate feedback and of course, carrying out a natural language dialogue with learners.

3 Overview of ITS "GeoMe"

GeoMe stands for "geometry for me". It is an ITS designed to help pupils in learning geometry by personalizing their learning paths. Geometry proving theorem is known to be very challenging for students to learn. Thus, almost all ITS proposed for geometry are dedicated to learning proof-writing with constructions, for instance: "Advanced Geometry Tutor" [7], "Advanced Geometry Proof Tutor" [8], ANGLE [9], AgentGeom [10], Geometry Explanation Tool [11] as new version of Geometry Cognitive Tutor.

Although many of these systems are used to provide supportive problem solving for advanced geometry, we intend to deliver learning material for elementary geometry to elementary schoolchildren. Therefore the knowledge model emphasizes the identification of basic shapes, properties of shapes, the shape's comparison etc.

Generally, ITS can take different views to implement the pedagogical criteria according to its educational scope that generates a classification into *specific* and *generic* ITS. According to [12], an ITS for ***generic domains*** is aimed to provide a framework to design and implement training proposal for multiple educational domains. GeoMe is an ITS for ***specific domain***, it uses pedagogical criteria suitable for just one specific educational domain. Basically, we intend to develop a tool that will help additionally to assimilate information regarding geometry lessons.

Unfortunately, in process of developing application we got some limitations regarding ***time***: according to [13] pupils of four grade daily could spend only 1 hour doing their homework for all their subjects. Thus, for all math' tasks pupils should spend only 10 minutes. Therefore, the time that a pupil needs to spend in our application should be even less. Taking in account time limitations, we decided to divide the features of our intelligent tutoring system as follows:

- *a session compartment*, where a pupil daily should spend no more than 8 minutes. Generally, we will reserve 3 minutes for theory and 5 for practice, but, in order to not stress the learners we will not add time counter. If some of them will need a few more minutes to finish their tasks, then we'll let them do so;
- *an interactive tool for 3D* visualization of shapes, the goal is to assist the users when needed, see Figure 1;

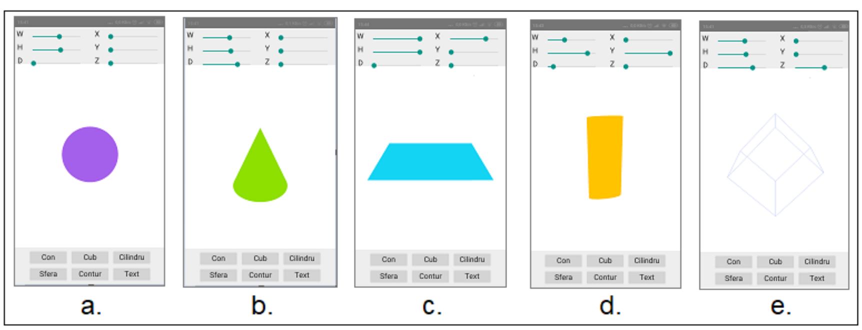

Figure 1. A few examples with interactive changing shapes: a) changing the circle's weight and height; b) changing triangle's depth, c) rotating square on axe X; d) rotating cylinder on axe Y; e) rotating cube's outline on axe Z

- *gamification compartment*, the goal is to help the users to rest while playing;
- *theoretical compartment*, the goal is also to assist the users when needed.

Even if the Ministry of Education, Culture and Research of the Republic of Moldova indicated that, for pupils in grades I-IV, the weekly volume of homework must not exceed 5 hours, we understand that all schoolchildren learn differently. Some of them can finish their tasks in the allocated time, but for the others it may take more efforts and more time.

In this regard, our task is not to overload pupil's homework by using our application, but finding a method that lets users spend less time studying while retaining the same amount of information. Well, one of the solutions can be applying the space repetition technique to session compartment. Regarding the other compartments, they should be designed as a way to rest while navigating in our application. It can be games or useful material that can be used not daily but wherever user wishes.

4 Spaced repetition

In order to make the most of session compartment we analyzed memory retention through spaced repetition. It is a method of reviewing material at systematic intervals. Spaced repetition technique is usually performed with flashcards. An ideal system of spaced repetitions allows user to review the material before it is forgotten, helping to retain information and transfer it from short-term memory to long-term memory.

4.1 Ebbinghaus' forgetting curve

We all know the phenomena when we ever tried to learn something new and been overwhelmed by the task, perhaps some of us succeeded in learning everything only to forget it all the next day. This aspect of human learning has been investigated during more than a century. Hermann Ebbinghaus, a German psychologist, first studied one of the simple memory models, the exponential forgetting curve [14], in 1885. He identified two critical variables that determine the probability of recalling an item: ***reinforcement***, i.e., repeated exposure to the item, and ***delay***, i.e., time since the item was last reviewed.

According to Ebbinghaus' forgetting curve, there is a strong correlation between time and memory. In fact, forgetting occurs rapidly at first, then it slows down; this process can be seen in the graph from Figure 2.

Figure 2. Ebbinghaus' forgetting curve

Generally, we forget about 60 percent of what we have just processed within the first 20 minutes. Moreover, more than half of memory loss that occurs is within the first hour. Most of material that will be forgotten is done so within the first 8 hours. Thus, the main question is *how to disturb the forgetting process?* Well, the theory goes that if we test ourselves, just as we are about to forget the thing that we have learnt, our brain will hold on to the information for longer, see Figure 3.

Every time we test our new knowledge, our brain will hold on to it for longer and longer. Another important question is *how do we know when to test ourselves when we do not know when we will forget it?* Another theory goes that if we test first time ourselves on what we have learnt, then we can remember it for 5^2 seconds, thus next time we should take the second test between 20-25 seconds and we will

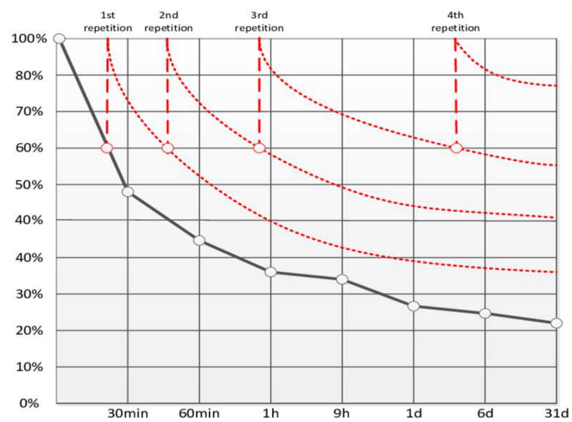

Figure 3. Ebbinghaus' forgetting curve and review cycle

remember it this time for 5^3 seconds. After the tenth time we will not need to test ourselves again for over a year.

Ebbinghaus's publication also includes an equation to approximate his forgetting curve:

$$S = 100 * \frac{1.84}{(log_{10}t)^{1.25} * 1.84}$$

S represents savings and is expressed as percentage. In other words, they are analogous to retention rate. **T** represents time in minutes. Savings of 100 percent would indicate that all items were still known from the first trial.

According to linguist Paul Pimsleur [15] by using audio reviewing for learning language, memory schedule should be as follows: 5 seconds, 225 seconds, 2 minutes, 10 minutes, 1 hour, 5 hours, 1 day, 5 days, 25 days, 4 months, 2 years. However, this approach is limited since the schedule is pre-recorded and cannot adapt to the learner's actual ability Another experiment have shown that if we memorize repeatedly within one hour, we will remember for one day, if we memorize one day later, we will remember for one week [16].

4.2 Leitner system

In our research we focus on one of the simplest and oldest spaced repetition methods, the Leitner system. Leitner [17] proposed a different repetition algorithm intended for use with flashcards. His system is more adaptive than Pimsleur method, since the spacing intervals can increase and decrease depending on students' performance. Figure 4 illustrates a popular variant of this method.

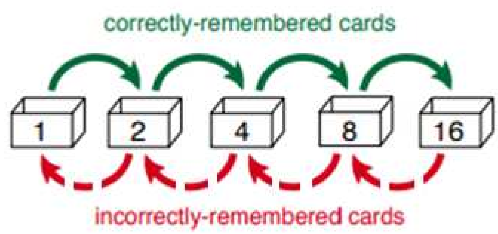

Figure 4. The Leitner System for flashcards

The main idea is to have a few boxes that will correspond to different practice intervals, such us the 1st day, the 2nd day and so on. Initially all cards will be placed in the 1st day box. When student practices, and if he remembers the correct answer, then that flashcard is promoted to the next box, otherwise, it will be demoted. Suppose, the student got the wrong answer from the 8th box, then that flashcard will be demoted to the 4th box.

5 Personal learning pathways

The main idea for our personal learning pathways is to give learners bits of information with different types of styles, repetitively at gradually increasing increments of time. In such way, learners would retain those bits of information for longer time periods each time. We intend to combine Ebbinghaus' memory models to Leitners' system.

Firstly, we have a collection with four learning styles for each task, such as textual format, visual, audio, sensorial. At the starting point, all tasks will be presented in textual format, afterword it will change by each repetition (see Figure 5).

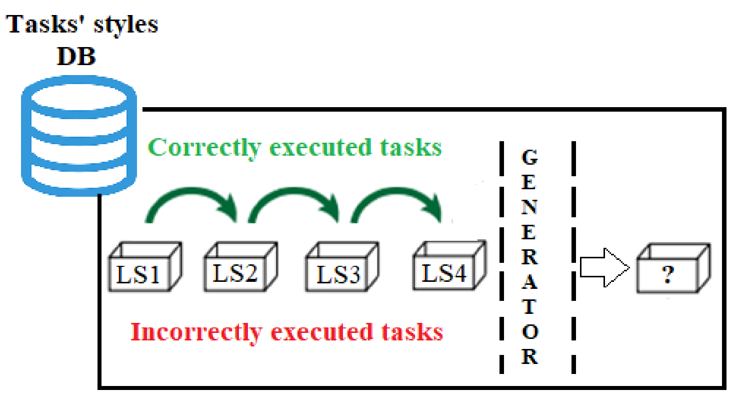

Figure 5. Task's learning style review cycle

It does not matter if previously the learner gave correct or incorrect answer, anyway, the same task at the new repetition will change its learning style. When the learner will walk through all four types of the same task, the generator will choose for the learner the most appropriated style based on statistics.

In such order, the learners will not be boring when repeating the same information. Moreover, studying the same information from different aspects will increase their memory retention.

Regarding schedule repetition, we believe that if the learner executed the task correctly in the 1st day, than he will remember how to solve it at least one more day, so the next time when the learner should repeat the same task should be on the 3rd day. On the 3rd day, if the learner answered correctly again, then the next repetition time should increase with one more day versus the previous one, so it will be on the 5th day.

In the case that the learner gave incorrect answer, the repetition will be right the next day. Taking into account that we have four learning styles, the schedule repetition for 5 subjects in our learning sessions will be as it is shown in Figure 6.

List of subjects	*Learning sessions review cycle*			
Point & Lines	1	3	6	10
Angles	2	4	7	11
Triangles	3	5	8	12
Squares	4	6	9	13
Circles	5	7	10	14
Learning style	***Textual***	***Audio***	***Visual***	***Sensorial***

Figure 6. Schedule repetition

Another question is *when we will stop repeating the same tasks?* Our theory goes that if the learner executes correctly for the four consecutive sessions, then the learner's memory retention is 100 percent, and application stops repeating the same task. In the case the learner gives incorrect answers after two repetitions, then his memory retention is equal to 50 percent, and application will generate the same task until the learner will get 100 percent. Additionally, in the case, when the learner gives four consecutive incorrect answers, then human expert is involved. All these cases are shown in Figure 7.

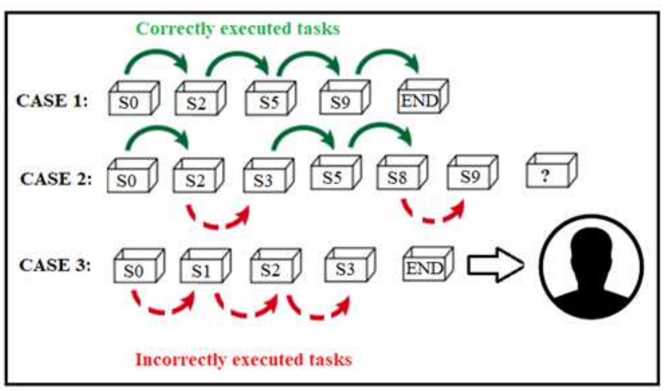

Figure 7. Task's review cycle examples

6 Conclusion

This paper presents a study of designing personal learning pathways for our intelligent tutoring system "GeoMe". Our main idea for designing personal learning pathways consists in adding different learning styles to schedule repetition based on Leitner system and Ebbinghaus' forgetting curve. In such way, we'll design personal learning pathways and we assume that it will adapt to learner's skills. The more correct answer the learners will give, the less tasks they will get daily and vice-versa the less correct answers, the more effort pupils should put in their learning process. Nevertheless, by repeating their lessons the memory retention will definitely increase. Moreover, on each repetition presenting material in different type of learning styles will help pupils to understand deeper their lessons.

References

[1] J. Clement, "Model based learning as a key research area for science education," *Inter. J. of Sci. Educ.*, vol. 22, no. 9, pp. 1041–1053, Sep. 2000.

[2] O. Caftanatov, "A new approach of designing the intelligent tutoring system GeoMe," *in Proc.The fifth Conf. of Mathematical Society of the Rep. of Moldova*, Chisinau, vol. 5, pp. 305–308, Sep. 2019.

[3] W.A. Canfield, "A web-based intelligent tutoring system," *Mathematics and Computer Education*, vol. 35, no. 2, pp. 152–158, 2001.

[4] P. Daśić *et al.*, "A review of intelligent tutoring systems in E-learning," *Fascicle of Management and Tech. Engineering.*, no. 3, pp. 85–90, Dec. 2016.

[5] D. Sleeman and J.S. Brown, "Introduction: Intelligent Tutoring Systems," in *Intelligent Tutoring Systems*, D. Sleeman and J.S. Brown, Eds. New York: Academic Press, pp. 1–11, 1982.

[6] J.R. Carbonell, “AI in CAI: An artificial-intelligence approach to computer-assisted instruction,” *IEEE Tran. on Man-Machine Systems*, vol. MMS-11, no. 4, pp. 190–202, Dec. 1970.

[7] N. Matsuda and K. VanLehn, “Advanced Geometry Tutor: An intelligent tutor that teaches proof-writing with construction,” in *AIED – 12th Int. Conf. on AI in Educ*, Jul. 2005, pp. 8.

[8] K. Wang and S. Zhendong, “Interactive, Intelligent Tutoring for Auxiliary Construction in Geometry Proofs,” *ArXiv Journal*, vol. 1/1722.07254, pp. 11, Nov. 2017.

[9] K.R. Koedinger and J.R. Anderson, “Effective use of intelligent software in high school math classrooms,” in *Proceedings of World Conf. on AI in Ed*, VA:AACE, pp. 8, 1993.

[10] P. Cobo, J.M. Fortuny, E. Puertas, and P.R. Richard, “AgentGeom: a multiagent system for pedagogical support in geometric proof problems,” *Inter. J. of Comp.for Math. Learning*, pp. 57–79, Apr. 2007. Available: DOI: 10.1007/s10758-007-9111-5.

[11] V. Alven, A. Ogan, O. Popescu, C. Torrey, and K.Koedinger, “Evaluating the effectiveness of a tutorial dialogue system for self-explanation,” *ITS2004, LNCS3220*, Springer-Verlag Berlin Heidelberg, pp. 443–454, 2004.

[12] M. Badaracco and L. Martínez, “An Intelligent tutoring system architecture for competency-based learning,” *KES 2011, Part II, LNAI 6882*, Springer-Verlag Berlin Heidelberg, pp. 124–133, 2011.

[13] Ministry of Education, Culture and Research of the Republic of Moldova, “Instruction: Homework management in primary, secondary and high school,” *Regulation*, pp. 1-26, Aug. 2018. Available on web site: http://particip.gov.md/proiectview.php?l=ro&idd=5622

[14] H. Roediger, “Remembering Ebbinghaus. A review of Memory: A Contribution to Experimental Psychology,” *Contemporary Psy-*

chology: A Journal of Reviews, vol. 30, no. 7, pp. 519–523, Jul. 1985.

[15] P. Pimsleur, "A memory schedule," *Modern Language Journal*, vol. 51, no. 2, pp. 73–75, Feb. 1967.

[16] D.R. Bacon and K.A. Stewart, "How fast do students forget what they learn in consumer behavior?: A longitudinal study," *Journal of Marketing Education*, vol. 28, no. 3, pp. 181–192, Dec. 2006.

[17] S. Leitner, "That is how you learn to learn," *Applied Learning Psychology - A Path to Success*, Freiburg im Breisgau, Basel, Wien: Verlag, Herder, 1972. (in German).

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