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Discovering Learner Styles in Adaptive e-Learning Hypermedia Systems

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Abstract: A distinct feature of an adaptive e-learning hypermedia system (AEHS) is the learner model it employs, that is, a representation of information about an individual learner. Learner modeling and adaptation are strongly correlated, in the sense that the amount and nature of the information represented in the learner model depend largely on the kind of adaptation effect that the system has to deliver. In fact, we see a problem arising when teachers assume similar learning styles, thinking styles, levels of knowledge and abilities for learners. This is because learners that are less able will feel that it is too difficult for them to follow and those that are more capable will feel as though the learning method is too easy. Teachers can adjust the standards; however, there may be conflicts between learners with varied styles. Thinking style, learning style, level of knowledge, preferences and ability of learner are part of learner's characteristics, which have significant influence on the activity of learners in the learning process. In this paper we have focused our attention on the learner model, which allows for the discovery of preferences, needs and interests of users that have access to an AEHS. In order to observe the psychological and pedagogical characteristics of a learner, a quantitative and qualitative research is conducted based on a questionnaire. The thinking style of a learner is analyzed. Based on the statistical results, we figure out the rules about pedagogical activity decision-making. This study presents two subsequent experiments. The first experiment explores the relationship of thinking style and pedagogical activities to validate this specific psychological construct in the context of an AEHS. The second experiment reduces the questionnaire to 60 questions, using a filtering principle keeping the validity of the original questionnaire.

Keywords: Learner model, E-learning, pedagogical activities, thinking style, adaptation
Categories: L.1.5, L.2.0, L.3.3, K.3

1 Introduction

In the last decade, the role of information technology for education has changed rapidly and significantly with the occurrence of e-Learning systems. E-Learning systems have increased their value with the growth and popularity of computer networks through the World Wide Web and the Internet [Vatcharaporn, 2011]. Combining the use of the Internet with potential teaching and learning methods offers new challenges and opportunities in distance education and e-Learning. E-Learning plays a major role in delivering educational material to the learners [Mukta, 2012].

The advantages of e-learning include classroom and platform independence. Even though currently there are many e-learning systems existing on the web, they commonly present the same materials to all students without considering individual differences [Dessislava, 2012]. In most web-based courses, the presented materials are only suitable for students who are homogeneous, highly prepared and motivated. When the web-based courses are used by a more diversified student population, it could reach efficiency limits, as these students may have very different learning aims, backgrounds, knowledge levels, learning styles, thinking styles and competencies. A web-based course intended for a certain group of students may not suitable for other students. Therefore a flexible web-based course is urgent to be designed so that different students obtain different learning materials and mode of presentations.
AEHS answer these problems modifying the presentation of materials to adjust each individual student, as well as making make an e-Learning system more effective by adapting the presentation of information and overall linkage structure to individual users in accordance with their knowledge and behavior [Vatcharaporn, 2011]. AEHS is based on the assumption that each learner has different learner-characteristics and that different educational settings can be more suitable for one type of learner than for another. When course content can be provided in a flexible way, adapted to individual learners' characteristics through the e-Learning system, the system can deliver the course content so that it capitalizes on the learner's characteristics in order to optimize the learning outcome [Brusilovsky, 1999; Brusilovsky, 2003] and [Shute, 2003].

The aim of AEHS is to provide appropriate information to the right student at the right time. This means that an adaptive e-Learning system is able to keep track of usage and to accommodate content automatically for each of the users, for the best learning result.

The next section depicts learner model in AEHS.

2 Learner modeling in AEHS

The learner model is an essential component in adaptive e-learning hypermedia system (AEHS). The adaptation of an e-learning system mainly involves choosing and presenting each successive teaching activity as a function of entire scope of learner's knowledge of the subject being taught and other relevant features of the learner, which are in turn maintained in a learner model. Therefore, the learner model is used to modify the interaction between system and learner to suit the needs of individual learners.

This section is aiming to look at different variables that can prompt adaptation and then discuss their potential use to a hypothetical learner model for AEHS. The objective of this work is to provide researchers, designers, and developers of AEHS a perspective to exploit research outcomes from the research area of personalised e-learning hypermedia system.

2.1 Preferences

One of the characteristics of learner which is important in adaptive e-learning is learner's preferences.

Preferences are learner features that relate to the learner's likes and dislikes. This variable describes that a learner can prefer some types of nodes and links to others or some parts of a page over others. Moreover, preferences can indicate interface elements such as preferred colors, fonts, navigation ways, etc. learner's preferences are not assumed by the system; instead the learner has to notify the system, directly or indirectly by providing feedback. Usually, the learner through checklists can select preferred interface elements. Once the preferences are determined the system generalizes the learner's preferences and applies them for adaptation in new contexts.

2.2 Goals

The goal of a learner is an adaptive variable that recently becomes popular in AEHS. It is an answer for the question what learners want to achieve in learning course. There are two kinds of goal: long-term and short-term. Long-term goal is relatively permanent in course. Moreover, learner can propose themselves long-term plans for lifelong study. By short-term goal, learner intends to solve certain problem such as: passing an examination, doing exercise… Short-term goal was also called as problem-solving goal.

Goals can be modeled through navigation monitoring, for example, by observing which links the learner visits more often.

2.3 Level Knowledge

Having an idea about the level of learner's knowledge plays a significant role in the field of personalized learning. In this work, regular tests are given from the learner at different stages of the learning process to identify the level of his knowledge. In other words, by assessing the knowledge of the learners, we can identify the level of them [Barbosa, 2012].

Based on the result of these tests, the system decides on the next stage of learning process. Therefore, considering the level of learner's knowledge can promote personalized learning performance.

2.4 Demographic data

We introduce the term demographic data to denote information about personal characteristics of the learner. While the learner can directly supply some demographic data, most data must normally be inferred from usage observations.

Demographic data, such as gender, age, language, and culture should be taken into account when designing AEHS to optimise learner's potential to benefit from the system's design in terms of knowledge acquisition. For example males and females appear to have different preferences in terms of media presentation, navigation support, attitudes, and information seeking strategies.

An empirical study into gender differences in AEHS reveals that males formulate queries comprising fewer keywords, spent less time on individual pages, click more hypertext links per minute and in general were more active while online than females.

Today's personalized e-learning hypermedia system in many cases operates on the basis of such demographic data.

2.5 Abilities

Learner's ability is determined to personalize learning content. [Chen, 2008] states that the difficulty level of the recommended content is highly relevant with the learner's ability. Furthermore, an inappropriate content can result in learner's cognitive overhead and disorientation during a learning process. Therefore, we propose a personalized e- learning system that delivers appropriate learning content for individual learners. In the first step, learner's ability initiates in moderate level. At different stages of learning, regular tests will be given from individual learner and the learner's responses will be analyzed according to Item Response Theory [Baker, 2001] to estimate and update dynamically learner's ability. In the next stage, appropriate content will be recommended based on updated ability [Yarandi, 2011].

2.6 Learning style

A learning style is defined as the characteristics, strengths and preferences in the way people receive and process information [Felder, 2005]. It refers to the fact that every person has its own method or set of strategies when learning.

We have selected the Felder model as the basis of our approach for the following reasons:

1. It has been successfully implemented in previous work when individually adapting the electronic learning material [Carver, 1999; Kinshuk, 2004; Prieto, 2004; Barbosa, 2005] and [Paredes, 2002].
2. It has been approved by its author and other specialists [Zywno, 2003; Felder, 2005].
3. It is user friendly and the results are easy to interpret, the number of dimensions is controlled and can actually be implemented [Shute, 2003].

This model rates the learner's learning style in a scale of four dimensions:

- **Sensitive (SEN):** Rather deal with facts, raw data and experiments, they're patient with details, but don't like complications.
- **Intuitive (INT):** Rather deal with principles and theories, are easily bored when presented with details and tend to accept complications.
- **Visual (VIS):** Easy for them to remember what they see: images, diagrams, time tables, films, etc.
- **Verbal (VER):** Remember what they've heard, read or said.
- **Active (ACT):** Learn by working in groups and handling stuff.
- **Reflexive (REF):** Learn better when they can think and reflect about the information presented to them. Work better alone or with one more person at most.
- **Sequential (SEQ):** Follow a lineal reasoning process when solving problems and can work with a specific material once they've comprehended it partially or superficially.
- **Global (GLO):** Take big intuitive leaps with the information, may have a difficulty when explaining how hey got to a certain result, need an integral vision.

Table 1 shows the learning style dimensions and media relationships:

a. Pedagogical activities

	VIS	VER	SEN	INT	SEQ	GLO	ACT	REF
Theory	☐	☒	☐	☒	☐	☒	☐	☒
Simulation	☒	☐	☒	☐	☒	☐	☒	☐
Synthesis	☒	☐	☐	☒	☐	☒	☒	☐
Explanation	☐	☒	☒	☐	☒	☐	☐	☒
Example	☒	☐	☒	☐	☒	☒	☒	☐

b. Multimedia formats

	VIS	VER	SEN	INT	SEQ	GLO	ACT	REF
Text	☐	☒	☐	☒	☒	☐	☐	☒
Image	☒	☐	☒	☒	☐	☒	☐	☒
Audio	☐	☒	☒	☒	☒	☐	☐	☒
Video	☒	☒	☒	☒	☒	☐	☐	☒
Animation	☒	☐	☒	☐	☒	☐	☐	☒
Hypertext	☐	☒	☐	☒	☒	☒	☐	☒

Table 1: Learning style dimensions and media relationships

2.7 Thinking style

Each person thinks and behaves in preferred ways that are unique to each individual. These dominant thinking styles are the results of the native personality interacting with family, education, work, and social environments [Danielson, 2002; Cano-García, 2000]. People's approaches to problem solving, creativity, and communicating with others are characterized by their thinking preferences [Harrison, 1984] and [Jabolokow, 2000]. For example, one person may carefully analyze a situation before making a rational, logical decision based on the available data. Another may see the same situation in a broader context and look for several alternatives. One person will use a very detailed, cautious, step-by-step procedure. Another has a need to talk the problem over with people and will solve the problem intuitively.

Thought processes have been studied since ancient history, several models have been proposed on how the human brain works. One of the well-known models is the Herrmann model [Bono, 1998; Abdel-Galil, 2003; Aleid, 2005] and [Herrmann, 1995; Haik, 2003; Chedru, 2010], which divide the brain into a four-quadrant brain dominance model.

These quadrants are located in the left and right hemispheres (left and right brain):

- **Left cerebral hemisphere (**Theoreticians**):** They like the facts, the details, critical cognitive, the precise definitions, unambiguous instructions.
- **Left limbic system (**Organiser): They love the instructions step by step, the schemas, checklists, time lines, problem solving with the steps and specific procedures.
- **Right limbic system (**Humanitarians): They prefer collaborative learning, group discussions, role-playing, personal approaches and personal examples.
- **Right cerebral hemisphere (**Innovators): They prefer brainstorm, metaphors, illustrations, images, summaries, holistic approaches, the pace (rhythm) alert.

The learner model in this work was defined as seven elements, which are regrouped into ontology [Barbosa, 2012] (see figure 1):

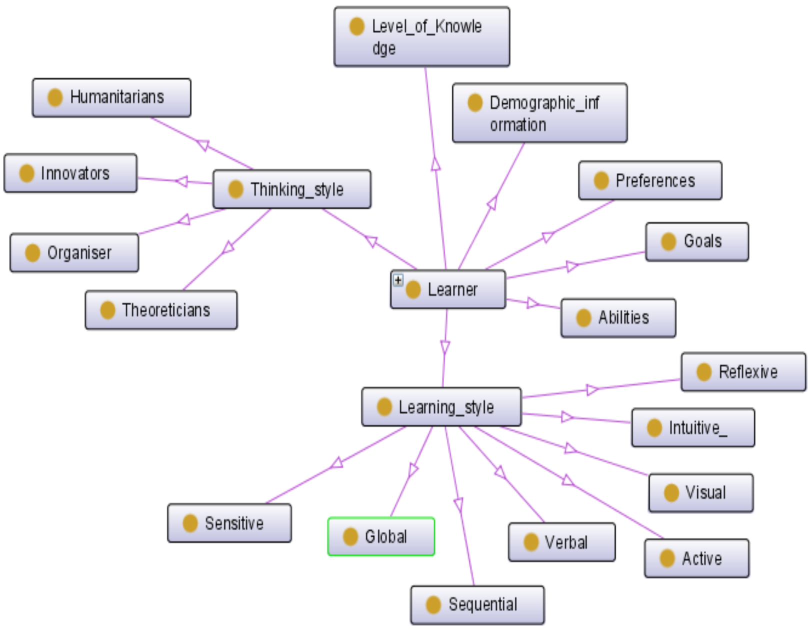


Figure 1: Graphical representation of learner model Ontology

The thinking style takes a central place in learner model. Depending on the style model, characteristics of learners may have varying degrees in the relevant thinking styles.

The next section explores the relationship of thinking style and pedagogical activities to validate this specific psychological construct in the context of AEHS.

3 Psychological questionnaire design

In this section, we begin with a psychological research observing learner's decision-making behavior for pedagogical activities; and then from the aspects of thinking style.

3.1 Instrument

A psychological questionnaire was designed. It mainly includes two parts:

(1) A series of questions consisting of statements about the pedagogical activities;
(2) A test of thinking style.

The pedagogical activity items are classified in two groups: presentation of theory and practical application. These activities are categorized in 12 types. For the presentation of theory, eight activities are provided: AG1 (the course structured in learning objectives), AG2 (additional information for the course), AG3 (the course based on examples and analogies), AG4 (multiple-choice questions), AG5 (little theoretical activity), AG6 (little theoretical in groups), AG7 (large theoretical activity), AG8 (large theoretical activity in groups). For the practical application, four activities provided: AG9 (little practical application), AG10 (little practical application in groups), AG11 (great practical), AG12 (great practical in groups). The provision of these activities are the absorption from the research of [Reigeluth. 1983; Merrill, 1983] and [Jonassen, 1999]. Being inspired by the research of [Jonassen, 1999; Skinner, 1938] and [Nelson, 1965]

In part 2 of our questionnaire, the test of thinking style is derived from the model of HBDI and includes 128 statements of daily life (see figure 2). This test has been applied and has been validated in university of Annaba.

During the interview session, we also noticed that the thinking style test was time consuming. In average, 18 minutes are needed to fulfill all the questions, which may make a respondent not very comfortable and become impatient at last; the repetitions and similarities of the questions make them feel vexed.

Normally, people have a limited attention span. Through the observation for 7 respondents, we found that the length of time that they feel appropriate is 5-7 minutes, and for our thinking style test, the average number of questions that they complete in this span is between 50 and 65 questions. Hence, we reduced this test to 60 questions, using a filtering principle keeping the validity of the original questionnaire.

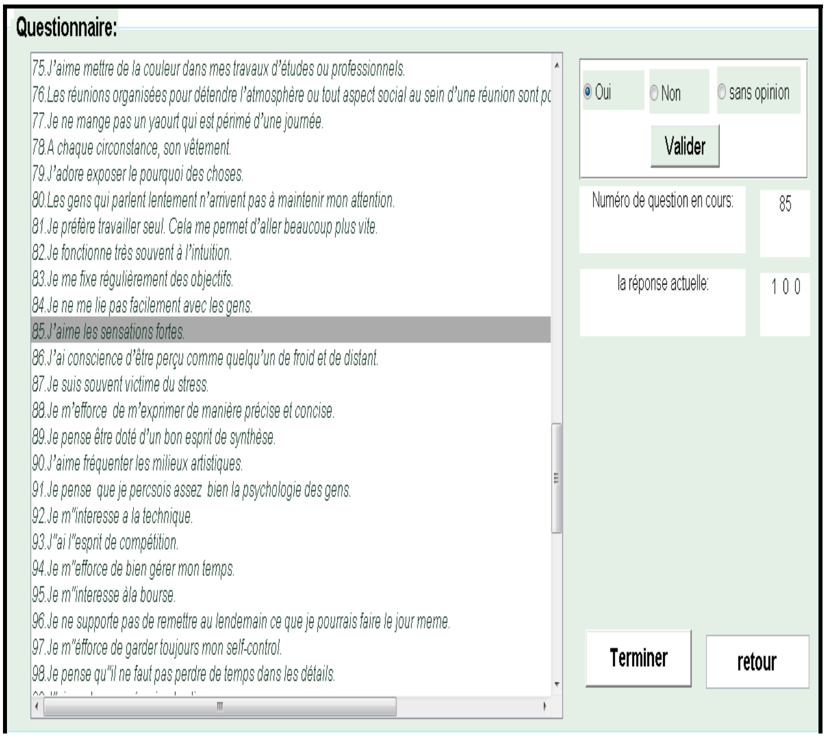


Figure 2: An example of the answers for thinking style test using Matlab

3.2 Reduce of questionnaire

The principle of the reduction of original questionnaire is to reserve the most representative statements for each group of color (thinking style). Precisely, the statements chosen by certain group of style but not frequently chosen by the other groups are more representative for this style. Obviously, the filtration should be done in the premise that thinking styles of the respondents have been proved by the original questionnaire.

Every statement of each group (e.g. statement 101 of group “green”) is examined via three indicators p1, p2 and p3: p1 =n1/n2, n1 is the number of the respondents who are agree on this statement; n2 is the size of the sample. For example: in a sample of 52 respondents (n2=52), for statement 101, 27 persons agree on it (n1=27), therefore p1=0.519; p2=n3/n4, n3 signifies the total of the respondents who are agree on the statement excluding the ones whose thinking style does not belong to what this statement represent; n4 signifies the total of the respondent who has the thinking style that the statement represents. For the same sample, 18 persons among the 52 respondents have the “green” thinking style (n4=18), among them, 16 respondents agree on the statement 101 (n3=16), thus, p2=0.889.

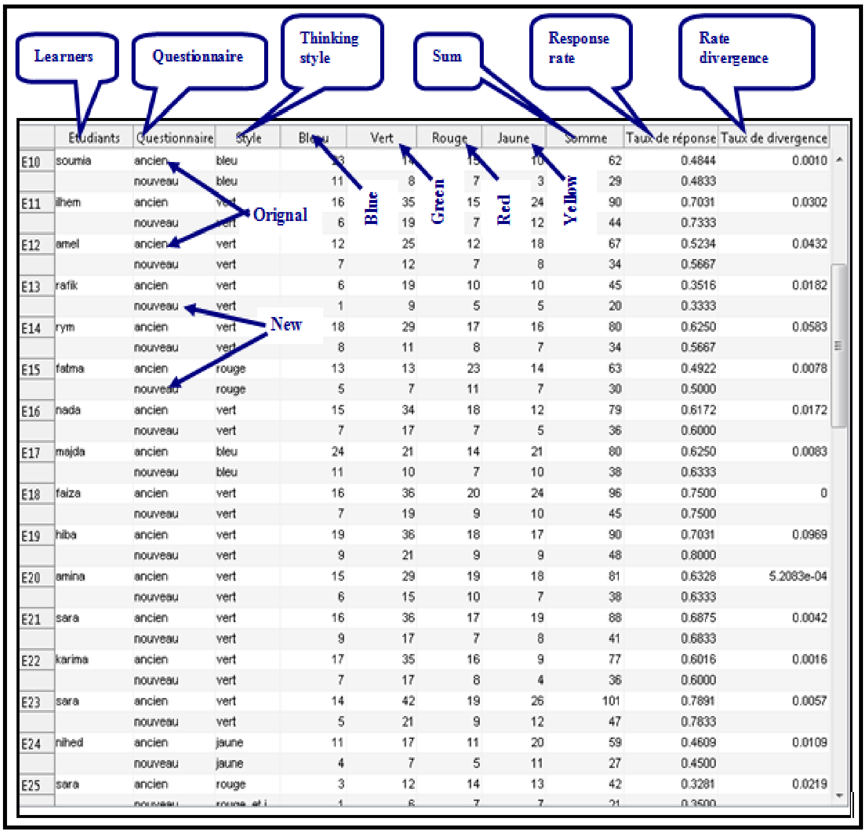
p3 = p2− p1, e.g. for statement 101, p3 = 0.370. The bigger p3 is, the more representative this statement will be.

After sorting p3, those statements without distinguished features are filtered.

Furthermore, for those statements containing complex words or sentences may also make the respondents confused. Hence, we get rid of these statements and reserve the simple ones of the original test. Thus, a thinking style test with 60 statements (15 statements in each group) is generated.

In order to verify the validity of the reform of test with 60 questions, we sent the 60-Question-questionnaire among a group of learners who have different thinking styles. The original results and the new results are listed in figure 3.

In figure 3, sum is the total of responses of "OUI" (YES) in thinking style test for a learner. The rate of response is calculated by "sum/128" and "sum/60" separately, 128 and 60 are the number of statements of original test and new test. The last column shows the divergence (response rate of new test minus response of original one); the values of percentage in this column are all positive. Thus, we can draw a general conclusion: after reformation, the response rate of test has been greatly elevated. It means that, in e-learning platform, our new test with 60 statements is more efficient than the original one.



	Etudiants	Questionnaire	Style	Bleu	Vert	Rouge	Jaune	Somme	Taux de réponse	Taux de divergence
E10	soumia	ancien	bleu	[illegible]	[illegible]	15	10	62	0.4844	0.0010
		nouveau	bleu	11	8	7	3	29	0.4833	
E11	ilhem	ancien	vert	16	35	15	24	90	0.7031	0.0302
		nouveau	vert	6	19	7	12	44	0.7333	
E12	amel	ancien	vert	12	25	12	18	67	0.5234	0.0432
		nouveau	vert	7	12	7	8	34	0.5667	
E13	rafik	ancien	vert	6	19	10	10	45	0.3516	0.0182
		nouveau	vert	1	9	5	5	20	0.3333	
E14	rym	ancien	vert	18	29	17	16	80	0.6250	0.0583
		nouveau	vert	8	11	8	7	34	0.5667	
E15	fatma	ancien	rouge	13	13	23	14	63	0.4922	0.0078
		nouveau	rouge	5	7	11	7	30	0.5000	
E16	nada	ancien	vert	15	34	18	12	79	0.6172	0.0172
		nouveau	vert	7	17	7	5	36	0.6000	
E17	majda	ancien	bleu	24	21	14	21	80	0.6250	0.0083
		nouveau	bleu	11	10	7	10	38	0.6333	
E18	faiza	ancien	vert	16	36	20	24	96	0.7500	0
		nouveau	vert	7	19	9	10	45	0.7500	
E19	hiba	ancien	vert	19	36	18	17	90	0.7031	0.0969
		nouveau	vert	9	21	9	9	48	0.8000	
E20	amina	ancien	vert	15	29	19	18	81	0.6328	5.2083e-04
		nouveau	vert	6	15	10	7	38	0.6333	
E21	sara	ancien	vert	16	36	17	19	88	0.6875	0.0042
		nouveau	vert	9	17	7	8	41	0.6833	
E22	karima	ancien	vert	17	35	16	9	77	0.6016	0.0016
		nouveau	vert	7	17	8	4	36	0.6000	
E23	sara	ancien	vert	14	42	19	26	101	0.7891	0.0057
		nouveau	vert	5	21	9	12	47	0.7833	
E24	nihed	ancien	jaune	11	17	11	20	59	0.4609	0.0109
		nouveau	jaune	4	7	5	11	27	0.4500	
E25	sara	ancien	rouge	3	12	14	13	42	0.3281	0.0219
		nouveau	rouge_et_j	1	6	7	7	21	0.3500	

Figure 3: Original responses and new responses for thinking style test

In Figure 4, we can observe the tendency of thinking style among these learners in four thinking style groups. It shows that our new test of thinking style is generally consistent with the original one.

3.3 Thinking style and pedagogical activities

With the thinking style test, theoretician, organizer, humanitarian (social), innovator, or the combination of them can be identified as the people who have thinking style of “blue”, “green”, “red” and “yellow”. The data we collected may give us implications on activity recommendation adapting to this psychological characteristic of learner.

3.3.1 Data processing on thinking style

In thinking style test, statements are grouped into four colors: blue, green, red and yellow, which signify the corresponding thinking styles. For data processing, every chosen item is given a value: “1” represents the agreement with the statement, “0” represents “not agree”. Besides “Yes”, “No”, the third choice “no opinion” with the weight of “0.4” is for observing the preference tendency more precisely between definitely “Yes” and definitely “No”. There are also the cases in which a respondent has two or three dominant preferences even four, signifying that he or she has similar degrees on more than one thinking style. The existing research indicates that people may use more than one style primarily. Each person can have primary preferences (areas of the brain he or she goes too easily and enjoys), secondary preferences (areas of the brain that can be and are accessed when necessary) and tertiary preferences (areas a person may have difficulty accessing or may even avoid) [Chedru, 2010]. We choose the following algorithm to identify which are the dominant thinking style preferences for a learner.

The thinking style identification should be consistent with following Matlab command (see figure 4, figure 5):

In figure 6, we regard di (i=1, 2, 3, 4) as the values of a respondent’s four quadrants of preferences, and rank them: d1> d2> d3> d4, suppose:

$$s = d1 + d2 + d3 + d4 \;;$$
$$e = \frac{d1 - d2}{s} \;;$$
$$f = \frac{d2 - d3}{s} \;;$$
$$g = \frac{d3 - d4}{s} \;.$$

The thinking style identification should be consistent with following rules:

- If 0.015 < e, then the style of d1 is the unique dominance (i.e. the respondent has the unique thinking style of the group that d1 represents;
- If 0.015 > = e, then observe f:
- If 0.015 < f, then d1 and d2 are the two dominances;
- If 0.015 > = f, then observe g:
- If 0.015 < g, then d1, d2 and d3 are the three dominances;

- Else d1, d2, d3 and d4 have the same dominance degree. It means that the user has a "whole brain" thinking style.

The indicator of "No opinion" can be employed as the reference for identifying the tendency once the dominant values appear to be the same.

3.3.2 Data analysis on thinking style and pedagogical activities

In thinking style test, to examine the corresponding pedagogical activities of certain thinking style, we observe the data from 58 respondents of which total number of response items is more than 64 (see figure 7).

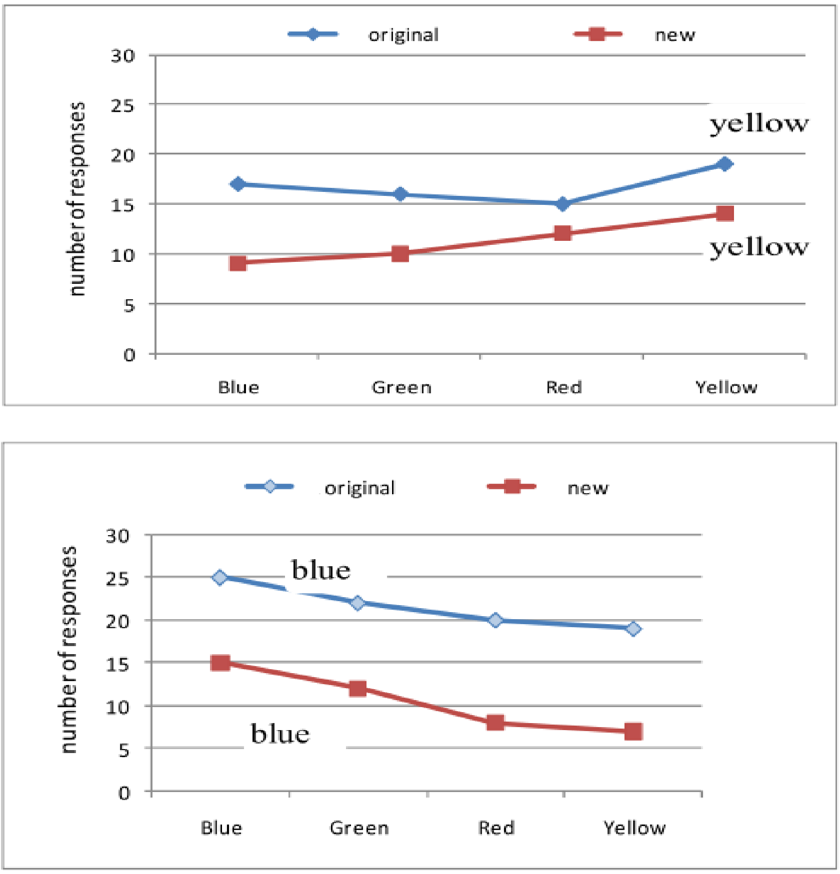


Figure 4: The comparison of the responses between original and new thinking style test (yellow and blue)

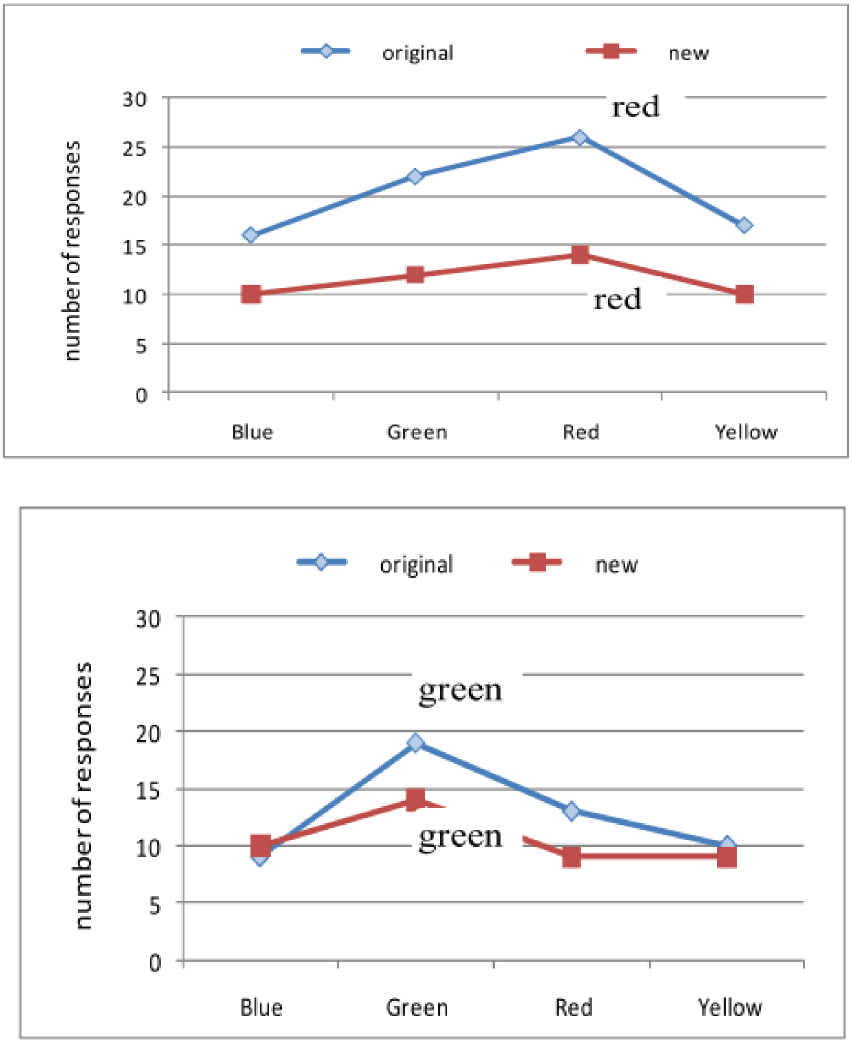


Figure 5: The comparison of the responses between original and new thinking style test (red and green)

```
s=sum(d);
e=(d(1)-d(2))/s;
f=(d(2)-d(3))/s;
g=(d(3)-d(4))/s;
mes1=contenu(I(1));
mes2=[contenu(I(1)) ' et ' contenu(I(2)) ' ' '  sont les deux dominances'];
mes3=[contenu(I(1)) ' et ' contenu(I(2)) ' et ' contenu(I(3)) ' sont les trois dominances'];
mes4=[contenu(I(1)) ' ,' ' ' contenu(I(2)) ' , '  contenu(I(3)) ' et ' contenu(I(4))  '  ' 'sont les quatres dominances'];

if e>0.015
    set(handles.text1,'string',mes1)
    etudiants(numero_utilisateur).style1=mes1;
else
    if f>0.015
        set(handles.text1,'string',mes2)
        etudiants(numero_utilisateur).style1=mes2;
    else
        if g>0.015
            set(handles.text1,'string',mes3)
            etudiants(numero_utilisateur).style1=mes3;
        else
            set(handles.text1,'string',mes4)
           etudiants(numero_utilisateur).style1=mes4;
        end
    end
end
```

Figure 6: The thinking style identification using Matlab

The goal for launching the questionnaire is to recommend pedagogical activities for learner based on learners' features. For observing the probabilities of the pedagogical activities in condition of thinking style, we use Bayes' theorem in probability theory [Bayes, 1763].

The key idea of Bayes' theorem is that probability of event A given event B depends not only on the relationship between A and B but also on the absolute probability of A not concerning B.

	AG1	AG2	AG2	AG4	AG5	AG6	AG7	AG8	AG9	AG10	AG11	AG12
bleu	0.3333	0	0	0	0	0	0.3333	0	0	0	0.3333	0
bleu	0	0.2000	0.2000	0.2000	0	0.2000	0	0	0	0.2000	0	0
vert	0.2500	0.2500	0	0	0.2500	0	0	0	0	0	0	0.2500
vert	0.3333	0	0	0	0.3333	0	0	0	0	0.3333	0	0
vert	0	0.3333	0	0	0	0	0	0.3333	0	0	0.3333	0
vert	0	0.3333	0	0	0	0.3333	0	0	0	0.3333	0	0
vert	0	0.2500	0	0	0.2500	0	0	0	0.2500	0	0.2500	0
vert	0.2500	0	0	0	0.2500	0	0	0	0.2500	0	0	0.2500
vert	0.2500	0	0	0	0.2500	0	0	0	0.2500	0	0	0.2500
vert	0.2000	0	0	0	0.2000	0	0	0.2000	0	0.2000	0	0.2000
vert	0.2000	0	0.2000	0	0.2000	0	0.2000	0	0	0.2000	0	0
vert	0.2500	0	0.2500	0.2500	0	0	0	0	0	0	0	0.2500
vert	0.2500	0	0.2500	0	0	0.2500	0	0	0.2500	0	0	0
vert	0	0	0	0.2500	0.2500	0	0	0.2500	0	0.2500	0	0
vert	0	0	0	0.2500	0	0.2500	0	0	0.2500	0	0	0.2500
vert	0	0.3333	0	0	0.3333	0	0	0	0.3333	0	0	0
vert	0.2500	0	0	0.2500	0	0	0	0	0	0.2500	0	0.2500
vert	0	0.2000	0	0.2000	0	0	0	0.2000	0	0.2000	0	0.2000
vert	0.3333	0	0	0	0	0.3333	0	0	0	0.3333	0	0

Affichage | Affichage style/action

	AG1	AG2	AG3	AG4	AG5	AG6	AG7	AG8	AG9	AG10	AG11	AG12	Sum
blue	0.3333	0.2000	0.2000	0.2000	0	0.2000	0.3333	0	0	0.2000	0.3333	0	2.0000
vert	2.5667	1.7000	0.7000	1.2000	2.3167	1.1667	0.2000	0.9833	1.5833	2.1000	0.5833	1.9000	17
rouge	0.2500	0.2500	0	0	0.2500	0.7500	0	0	1	0	0.2500	0.2500	3
jaune	0.8667	0.2500	0	0.8667	0.2500	0	0.2000	0.2500	0.6667	0.2000	0.2500	0.2000	4
Sum	4.0167	2.4000	0.9000	2.2667	2.8167	2.1167	0.7333	1.2333	3.2500	2.5000	1.4167	2.3500	26.0000

Figure 7: The probability distribution according to activity and thinking style using Matlab

The simple statement of Bayes' theorem is

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}.$$

P(A) is the prior probability or marginal probability of A. It is "prior" in the sense that it does not take into account any information about B.

P(A\B) is the conditional probability of A given B. It is also called the posterior probability because it is derived from or depends upon the specified value of B;

P(B\A) is the conditional probability of B given A. It is also called the likelihood;

P(B) is the prior or marginal probability of B:

$$P(B) = P(A,B) + P(A^c,B) = P(B|A)P(A) + P(B|A^c)P(A^c)$$

Where A^c is the complementary event of A, so an alternative form of the theorem is

$$P(A|B) = \frac{P(B|A)P(A)}{P(B|A)P(A) + P(B|A^c)P(A^c)}.$$

More generally, for any A_i in the partition, Bayes' theorem states that

$$P(A_i|B) = \frac{P(B|A_i)P(A_i)}{\sum_{j=1}^{n} P(B|A_j)P(A_j)}, (j = 1,2,\ldots,n).$$

Bayes' theorem in this form gives a mathematical representation of how the conditional probability of event A given B is related to the converse conditional probability of B given A.

In our research, event A is that the learner chooses pedagogical activity and event B is that the learner who have thinking style; n is the number of types of pedagogical activity (n=12).

From figure 7, we can get the probabilities of choosing each activity regardless of any other information (regardless of thinking style) P(A) and the conditional probabilities of "thinking style" given "choosing certain activity" P(B\A) (see Table 2).

	P(A)	***P(blue\A)***	***P(green\A)***	***P(red\A)***	***P(yellow\A)***
AG1	0 ,17	0,32	0,49	0,12	0,08
AG2	0,09	0,56	0,15	0,15	0,14
AG3	0,13	0,07	0,2	0,07	0,66
AG4	0,06	0,2	0,54	0,2	0,05
AG5	0,06	0,26	0,22	0,19	0,33
AG6	0,15	0,08	0,03	0,82	0,06
AG7	0,03	0,41	0,11	0,27	0,21
AG8	0,073	0,047	0,059	0,815	0,078
AG9	0,06	0,1	0,23	0,1	0,58
AG10	0,06	0,139	0,066	0,663	0,132
AG11	0,044	0,079	0,079	0,13	0,713
AG12	0,07	0,05	0,08	0,7	0,171

Table 2: Prior probability of choosing pedagogical activity and conditional probability given thinking style

From Table 2, we can calculate the probability of choosing a pedagogical activity given that the learner who have thinking style.

For example, for the learners who have thinking style "blue":

P(Ag1\Blue)= P(Blue\Ag1)*P(Ag1)/ (P(Blue\Ag1)*P(Ag1)+ P(Blue\Ag2)*P(Ag2)+ P(Blue\Ag3)*P(Ag3)+ P(Blue\Ag4)*P(Ag4)+ P(Blue\Ag5)*P(Ag5)+ P(Blue\Ag6)*P(Ag6)+ P(Blue\Ag7)*P(Ag7)+ P(Blue\Ag8)*P(Ag8)+ P(Blue\Ag9)*P(Ag9)+ P(Blue\Ag10)*P(Ag10)+ P(Blue\Ag11)*P(Ag11)+ P(Blue\Ag12)*P(Ag12))= 0.27

Then, for the given thinking styles, the probability of choosing pedagogical activities can be obtained (see Table 3):

	P(A\blue)	P(A\green)	P(A\red)	P(A\yellow)
AG1	0,27	0,39	0,06	0,06
AG 2	0,26	0,07	0,04	0,05
AG3	0,05	0,12	0,03	0,37
AG4	0,07	0,17	0,04	0,02
AG5	0,08	0,07	0,03	0,09
AG6	0,067	0,021	0,358	0,04
AG7	0,07	0,02	0,03	0,03
AG8	0,02	0,02	0,17	0,02
AG9	0,03	0,07	0,02	0,15
AG 10	0,048	0,021	0,127	0,038
AG 11	0,018	0,017	0,017	0,137
AG 12	0,018	0,028	0,148	0,055
	1	1	1	1

Table 3: Probability of choosing pedagogical activity given thinking style (sample size=58)

In Table 3, for learners who have "blue" thinking style, the probabilities of choosing pedagogical activities AG1(0.27), AG2(0.26), AG5(0.08), AG7(0.07) and AG4(0.07) much higher (>0.05) than those of AG3(0.05), AG9(0.03), AG10(0,048), AG11(0,018) and AG12(0,018). This result is accord with the Hermann's Whole Brain theory that people of this style like "the facts, the logical problem-solving, and the unambiguous instruction".

Learners owning style of "green" show interest in AG1 (0,39), AG3(0,12), AG4(0,07), AG5(0,07) and AG9(0,07). In this case, Hermann's point of view on the "turn-on" work of style "yellow" is verified: "integrating ideas and concepts, exploring".

For the learners of "red" style, AG1 (0, 06), AG6 (0,358), AG8 (0, 17), AG12 (0.148) and AG10 (0,127) are accepted.

Learners owning style of "yellow" show interest in AG1(0,06), AG3(0,37), AG9(0,15), AG5(0,09) and AG11(0,137).

In general, AG1 can be accepted by the groups of "blue" and "green" (which is accord again with the statement in Whole Brain theory: the "green" one as an organizer likes to "integrate information in a sequential manner"); furthermore, AG4 is rarely accepted as a preference. The highest probability of choosing AG6 appears in group "red". In other words, they accept little theoretical in groups than the other groups of style.

All of these results signify that the sample is representative and can act as basis for further research. The recommending activities for the four thinking styles are listed in figure 8.

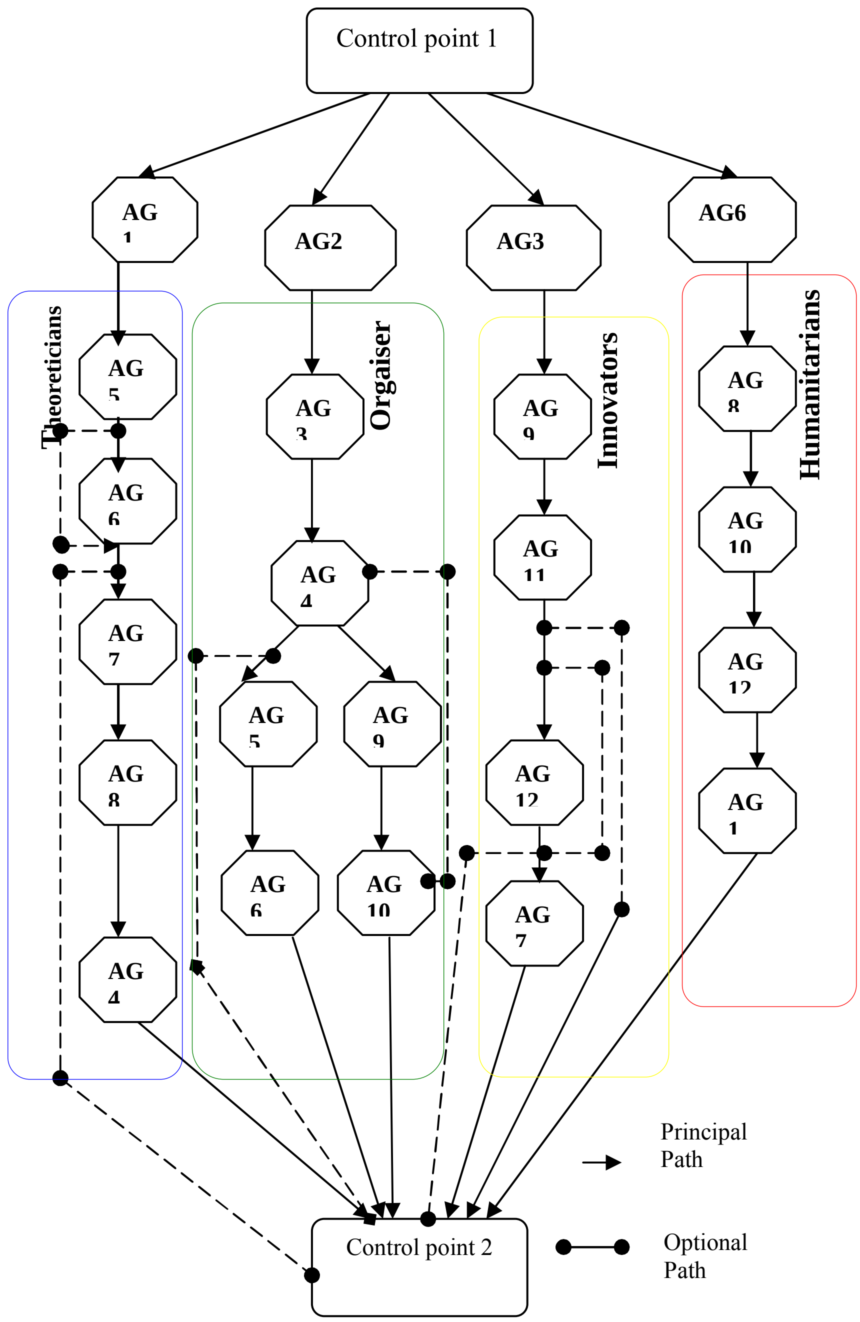


Figure 8: The recommending activities for the four thinking styles

Based on previous results, we propose the following pedagogical approach:

Theorist (blue): Teachers begin by presenting additional information theory, and they offer individual exercises for learners to make learning easier, after the learners attempt to solve individual problems.

Organizer (green): Teachers begin by presenting a formal course in several learning objectives, and they offer an overall assessment in the form of multiple choice questions.

Innovator (yellow): Teachers begin by illustrating it through examples and analogies, then offer individual learners to solve small practical applications, and finally the students are trying to solve large practical applications individually.

Social (red): Teachers offer learners to solve small activities theory in groups, then, learners try to analyze and solve big problem in groups, after they go through analysis of small practical applications in groups, therefore the teacher wants the learners to solve large practical applications in groups.

4 Conclusion and future work

Adaptive e-Learning is an enhancement that makes e-Learning systems more effective by adapting the presentation of information and overall link structure to the individual user, based on her/his knowledge and behavior. The aim of adaptive E-learning hypermedia system (AEHS) is to provide the right student with the right information at the right time. An adaptive system is based on three principal models: a domain model (which is all about domain content for teaching), a learner model (which collects all necessary learner information), and an adaptation model (which is used in adaptation by combining both a domain model and a learner model).

In this paper we have presented an adaptive learner model aimed at discovering the learner's preferences about the educational materials over time. This model is very suitable in adaptive e-learning hypermedia system (AEHS) that needs to "filter" the great volumes of information available, so that their learners can make a better use of it. To discover the learner's preferences we use the information about thinking styles represented in the learner's thinking style model.

In our research, the instrument developed for testing user's thinking style is proved valid and effective. By responding the daily life statements, a user could easily get his or her profile, with which system could automatically recommend the corresponding pedagogical activities for structuring course.

At the present we are working on the adaptation of the Bayesian networks to detect thinking styles.

A useful direction for future development will be the implementation of adaptability according to the learner model. Moreover, an important area of adaptability in which the adaptive platform may evolve includes the ability to create adaptive tests. In this way, teachers will have an opportunity for both adaptive content delivery and adaptive evaluation of learners.

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