Int J Edu Sci, 15(1,2): 134-141 (2016)
PRINT: ISSN 0975-1122 ONLINE: 2456-6322
DOI: 10.31901/24566322.2016/15.01-2.15

Weighing of Learning Factors Using Fuzzy Analytical Hierarchy Process

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KEYWORDS Comparison. Multi-criteria Decision-making Technique. School. Student. Teacher

ABSTRACT There are some factors that affect learning to a greater or lesser extent while performing learning activities. Research results reveal that many factors affect learning. This study aims to weight the factors**,** which affect learning. Factors**,** which affect the learning of primary school students were identified, and experienced elementary school teachers benefited from determining the importance of these factors. A fuzzy analytical hierarchy process associated with a multi-criteria decision-making technique was applied to determine the weight of each factor. The fuzzy logic was used to develop realistic results in terms of the analytical hierarchy process, a method based on a pairwise comparison of the factors. The consistency ratio was also examined to understand whether or not the binary consistency rate and pairwise comparisons are consistent. Thus, it is determined which factors are most important in affecting a child's learning. It also constitutes an input for determining which learning activities are most effective.

INTRODUCTION

Today, the importance of knowledge increases day by day. There has been an increased importance in contemporary education in recent years. The learning covers to changes in the behavior of individuals.

Learning is defined as relatively permanent changes, which occur with regard to knowledge and behaviors in terms of people's past experience (Mayer 1982). In learning, there are five aspects, which consist of the learner, learning, what is learned, what is taught and the learning environment. Even though two of these items may not directly affect learning, the rest of the items are influenced by them, and hence, they affect learning in an implicit way (Seven and Engin 2008).

Several studies have shown the effect of different elements on learning. For instance, Giannakos (2013) claims that learning performance can increase with the use of educational games. Kanthawongs and Kanthawongs (2013) assert that individual and social elements have an impact on learning management systems. Nursing students require belongingness and self-regard for learning (Kim and Park 2011). Peters et al. (2016) examined individual and organizational learning. The factors affecting the learning of higher education students are examined by Merhi (2015), while the factors influencing the learning of workers in the automotive factory by Karaali et al. (2011).

Rasul and Bukhsh (2011) investigated students' performance in terms of exam results, which are a part of education. According to this, extrinsic, intrinsic, personal and miscellaneous factors can affect the students when it comes to examinations. Prasangani (2015) alleges that learning English is related to a learner's self-concept. Motivation, attitude and anxiety also have an impact on learning English (Henter 2014).

Haraldseid et al. (2015) assert that nursing students' learning can depend on the physical, psychosocial and organizational environment. According to Serin et al. (2009), the factors, which affect learning, are motivation, study aids, anxiety and identifying the main ideas.

Ozerbas (2015) stresses that young teachers are more adaptable than experienced teachers, and class teachers are regarded as the best teachers within all branches with respect to applying new curriculum and their remarks.

The Fuzzy Analytic Hierarchy Process (FAHP) applications have been implemented in many sectors. These sectors are the healthcare sector (Buyukozkan and Ciftci 2012; Podgórski 2015), the public sector (Huang et al. 2008; Kaya and Kahraman 2011; Kaya and Kahraman 2011a), and the manufacturing sector (Chan and Kumar 2007; Duran and Aguilo 2009; Rostamzadeh and Sofian 2011).

AHP, which involves verbal and numerical techniques, originated in the 1980s from work done by Saaty (1980). AHP determines the weight of criteria using pairwise comparison. At the same

time, it enables one to range the alternatives (Saaty 1980). Fuzzy AHP is broadened classical AHP. Fuzzy AHP consists of the following steps (Chang 1996):

Step 1: Determining criteria and creating a fuzzy scale: Triangle fuzzy numbers and scale valuations, which are determined for pairwise comparisons, are displayed in Table 1.

Step 2: Performing pairwise compari-sons: Based on Table 1, pairwise comparisons are performed.

Step 3: Calculating the Consistency Ratio: Pairwise comparisons are recalculated if the Consistency Ratio is greater than 0.1. Pairwise comparisons are performed in the matrix, after consistency has been measured (Equation (1) and Equation (2)). The Consistency Index (CI) and the Random Index (RI), which are provided in Table 2 are utilized in calculating the Consistency Ratio.

Consistency Index: $CI=(\lambda_{max}-n)/(n-1)$ (1)

Consistency Ratio: $CR=\text{Consistency Index}\,(CI)/\text{Random Index}\,(RI)$ (2)

Step 4: Selecting the fuzzy AHP method: Extending the fuzzy method to include triangular values as developed by Chang (1996) is preferred, since it is easy to implement.

Step 5: Implementing the fuzzy AHP method: $X=\{x_1, x_2,....,x_n\}$ objects cluster and $U=\{u_1, u_2,....,u_n\}$ target cluster. Thus, m extended analysis values for each object is shown by Equation (3):

$$M^1_{g1}, M^2_{g1},...M^m_{g1}, i=1,2,.....,n \quad (3)$$

Step 5.1: According to the i^{th} object, fuzzy artificial size values (Equation (4) and Equation (7)):

$$S_1=\sum_{j=1}^{m} M^j_g \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{gi}\right] \quad (4)$$

$$\sum_{j=1}^{m} M^j_{gi}=\left(\sum_{j=1}^{m}1_j, \sum_{j=1}^{m}m_j, \sum_{j=1}^{m}u_j,\right) \quad (6)$$

$$\sum_{i=1}^{m}\sum_{j=1}^{m} M^j_{gi}=\left(\sum_{i=1}^{n}1_j,, \sum_{i=1}^{n}m_j, \sum_{i=1}^{n}u_j,\right) \quad (7)$$

$$\left[\sum_{i=1}^{m}\sum_{j=1}^{m} M^j_{gi}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}u_j,}, \frac{1}{\sum_{i=1}^{n}m_j}, \frac{1}{\sum_{i=1}^{n}1_j,}\right) \quad (8)$$

Step 5.2: $M_2=(1_2,m_2,u_2) > M_1=(1_1, m_1, u_1)$ probability value (Equation (8) and Equation (9)):

$$V(M_2 \geq M_1)=\begin{cases} 1 & m_2 \geq m_1 \\ 0, & l_1 \geq u_2 \\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-1_1)} & \text{otherwise} \end{cases} \quad (9)$$

Step 5.3: The possibility of a fuzzy number, which is greater than other fuzzy numbers M_i (i=1,2,....,k) and the weighting vector (Equation (10) and Equation (12)):

$$V(M \geq M_1, M_2,...M_k)=V[(M > M_1), (M \geq M_2),..., (M \geq M_k)] = \min V(M \geq M_i),\ i=1,2,3,...k \quad (10)$$

$$d'(A_i)=\min V(S_i \geq S) \text{ for every } k=1,2,...n; k \# j \quad (11)$$

$$\text{Weighting vector } W=(d'(A_1),dA_2),...,d'(A_n)^T \quad (12)$$

Step 5.4: Performing Normalization Weighting Vector (Equation (13)):

$$W=(d(A_1), d(A_2),...,d(A_n))^T \quad (13)$$

The Objectives of the Study

In this study, education that adapts people to their environment and culture has an important place in anthropological aspects. These issues especially include social anthropology that contributes to the effectiveness of education. Education enables the development of the general public. Education is intertwined with the concept of learning.

This paper has benefited from multi-criteria decision-making techniques when it comes to digitizing the opinions of teachers. AHP was applied in order to weight the criteria. AHP with fuzzy logic has been applied in order to obtain realistic results. The weights of all the main and sub-criteria in terms of learning are determined at the end of the application of the fuzzy AHP method.

The remainder of this paper is organized as follows. The following section presents the methodology. In this section, the factors that affect learning are explained. The sections entitled Results and Discussion evaluate the results obtained through the use of fuzzy AHP. In the Conclusion, the researcher considers the weighting of the factors that affect learning. The researcher presents proposals in the Recommendations section.

METHODOLOGY

In this study, the viewpoints of eight primary school teachers in Kocaeli City in Turkey were firstly applied in order to determine the learning factors. Eight teachers' opinions were taken into consideration in order to ensure the validity of the evaluation. The researcher preferred experienced teachers in terms of directing the students. Afterwards, pairwise comparisons were

conducted in accordance with the opinions of the teachers.

The AHP method was employed to prevent false choices based on a subjective interpretation. The fuzzy AHP method, instead of AHP, was utilized to obtain more realistic results. According to the fuzzy AHP method, pairwise comparisons are performed for the main factors and sub-factors as shown in Table 1. Consistency ratios are calculated by considering the validity of the pairwise comparisons. The values that appear in Table 2 have been used in order to calculate these ratios.

The factors that were determined in this study consist of three main factors. These are factors regarding the learners(C1), the learning methods (C2) and the learning materials (C3). The factors regarding learners have eight sub-factors. These are species-specific behavior (C11), maturation (C12), motive (C13), general stimulated state (C14), transfer (C15), attention (C16), age (C17) and intelligence (C18).

The factors regarding learning methods have four sub-factors. These are topic structure (C21), time (C22), feedback (C23) and student activity (C24).

The factors regarding learning materials have three sub-factors. These are perceptual distinguishability (C31), conceptual sorting (C32) and semantic association (C33).

According to the eight teachers, the pairwise comparisons are in Table 3 with regard to the main factors. The pairwise comparisons are respectively in Tables 4, 5 and 6 for the sub-factors. The pairwise comparisons for learners are conducted in Table 4 by eight decision-makers. Similarly, the pairwise comparisons are conducted for learning methods in Table 5, while the pairwise comparisons are conducted for learning materials.

Table 3: Pairwise comparisons for main factors

Decision makers	*Main factors*	*C1*	*C2*	*C3*
Decision Maker 1	C1	E	EI	M
	C2		E	EI
	C3			E
Decision Maker 2	C1	E	EI	EI
	C2	E	E	
	C3			E
Decision Maker 3	C1	E	EI	EI
	C2		E	E
	C3			E
Decision Maker 4	C1	E	EI	M
	C2		E	EI
	C3			E
Decision Maker 5	C1	E	EI	EI
	C2		E	E
	C3			E
Decision Maker 6	C1	E	EI	EI
	C2		E	EI
	C3			E
Decision Maker 7	C1	E	EI	MI
	C2		E	EI
	C3			E
Decision Maker 8	C1	E	EI	EI
	C2		E	EI
	C3			E

RESULTS

The results of fuzzy AHP are displayed in Table 7. First of all, three main criteria are compared with each other. After that, pairwise comparisons for sub-criteria are conducted under heading main criteria. Global criteria weights are calculated by multiplying main criteria weights with sub-criteria weights.

The fuzzy AHP method is practiced for the three aspects of learning. According to this, the

Table 1: Linguistic terms for pairwise comparisons and fuzzy importance values

Verbal importance	*Fuzzy numbers*	*Scale values*
Equally important (E)	(1,1,1)	(1/1,1/1,1/1)
Intermediate values (EI)	(1,2,3)	(1/3,1/2,1/1)
Moderately important with one over another (M)	(2,3,4)	(1/4,1/3,1/2)
Intermediate values (MI)	(3,4,5)	(1/5,1/4,1/3)
Strongly important (S)	(4,5,6)	(1/6,1/5,1/4)
Intermediate values (SI)	(5,6,7)	(1/7,1/6,1/5)
Very strongly important (VS)	(6,7,8)	(1/8,1/7,1/6)
Intermediate values (VSI)	(7,8,9)	(1/9,1/8,1/7)
Extremely important (EX)	(8,9,9)	(1/9,1/9,1/8)

Table 2: Random Index

n	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Table 4: Pairwise comparisons for learners

Decision makers	*Main factors*	*C11*	*C12*	*C13*	*C14*	*C15*	*C16*	*C17*	*C18*
	C11	E	E	1/EI	1/EI	1/EI	1/EI	E	E
	C12		E	1/EI	1/EI	1/EI	1/EI	E	1/M
	C13			E	E	EI	EI	EI	1/EI
Decision	C14				E	E	E	EI	1/M
Maker 1	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/M
	C18								E
	C11	E	E	1/EI	1/EI	E	E	E	E
	C12		E	1/EI	1/EI	E	1/EI	E	1/EI
	C13			E	E	E	E	EI	1/EI
Decision	C14				E	E	E	EI	1/EI
Maker 2	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/EI
	C18								E
	C11	E	E	1/EI	1/EI	E	1/EI	E	E
	C12		E	1/EI	1/EI	E	1/EI	E	1/M
	C13			E	E	E	E	EI	E
Decision	C14				E	E	E	EI	1/EI
Maker 3	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/M
	C18								E
	C11	E	E	1/EI	1/EI	1/EI	E	E	E
	C12		E	1/EI	1/EI	1/EI	1/EI	E	1/M
	C13			E	E	E	E	EI	1/EI
Decision	C14				E	E	E	EI	1/EI
Maker 4	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/M
	C18								E
	C11	E	E	1/EI	1/EI	1/EI	1/EI	E	E
	C12		E	1/EI	1/EI	1/EI	1/EI	E	1/EI
	C13			E	E	E	E	EI	1/EI
Decision	C14				E	E	E	EI	1/EI
Maker 5	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/EI
	C18								E
	C11	E	E	1/EI	1/EI	1/EI	E	E	E
	C12		E	1/EI	E	E	E	E	1/M
	C13			E	E	E	E	EI	1/EI
Decision	C14				E	E	E	E	1/EI
Maker 6	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/M
	C18								E
	C11	E	E	1/EI	1/EI	E	1/EI	E	E
	C12		E	1/EI	1/EI	E	1/EI	E	1/EI
	C13			E	E	E	E	EI	1/EI
Decision	C14				E	E	E	EI	1/M
Maker 7	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/EI
	C18								1/EI
	C11	E	E	1/EI	1/EI	E	E	E	E
	C12		E	1/EI	1/EI	E	1/EI	E	1/M
	C13			E	E	E	E	EI	1/EI
Decision	C14				E	E	E	EI	1/EI
Maker 8	C15					E	E	EI	1/EI
	C16						E	EI	1/EI
	C17							E	1/M
	C18								1/EI

Table 5: Pairwise comparisons for learning methods

Decision Maker	*Main factors*	*C21*	*C22*	*C23*	*C24*
	C21	E	1/EI	E	1/EI
Decision	C22		E	EI	E
Maker 1	C23			E	1/EI
	C24				E
	C21	E	E	E	E
Decision	C22		E	E	E
Maker 2	C23			E	E
	C24				E
	C21	E	E	E	1/EI
Decision	C22		E	E	E
Maker 3	C23			E	1/EI
	C24				E
	C21	E	E	E	1/EI
Decision	C22		E	EI	E
Maker 4	C23			E	1/EI
	C24				E
	C21	E	E	E	1/EI
Decision	C22		E	EI	E
Maker 5	C23			E	E
	C24				E
	C21	E	E	E	1/EI
Decision	C22		E	EI	E
Maker 6	C23			E	1/EI
	C24				E
	C21	E	E	E	E
Decision	C22		E	E	E
Maker 7	C23			E	EI
	C24				E
	C21	E	E	E	E
Decision	C22		E	EI	E
Maker 8	C23			E	E
	C24				E

Table 6: Pairwise comparisons for learning materials

Decision Maker	*Main Maker*	*C31*	*C32*	*C33*
	C31	E	EI	E
Decision	C32		E	E
Maker 1	C33			E
	C31	E	E	E
Decision	C32		E	E
Maker 1	C33			E
	C31	E	E	E
Decision	C32		E	E
Maker 1	C33			E
	C31	E	EI	EI
Decision	C32		E	E
Maker 1	C33			E
	C31	E	EI	EI
Decision	C32		E	E
Maker 1	C33			E
	C31	E	EI	EI
Decision	C32		E	1/EI
Maker 1	C33			E
	C31	E	EI	EI
Decision	C32		E	EI
Maker 1	C33			E
	C31	E	EI	EI
Decision	C32		E	E
Maker 1	C33			E

factor regarding learners is 54.48 percent, the factor regarding learning methods is 30.38 percent and the factor regarding learning materials is 15.14 percent. Since the consistency ratio was under ten percent, pairwise comparisons were meaningful. The findings represent that learning has become prominent as the most important factor that affects learning. Learning methods and materials guides to learners for learning.

After weighting the criteria for each main aspect was undertaken, the sub-factors' weight was determined using fuzzy AHP. Since the consistency ratio was under ten percent, pairwise comparisons were meaningful. The sub-factors regarding learners are species-specific behavior (3.57%), maturation (3.03%), motive (9.13%), generally stimulated state (8.32%), transfer (7.16%), attention (7.71%), age (2.94%) and intelligence (12.62%). Intelligence is the most significant factor within the factors regarding learners.

The sub-factors regarding learning methods are topic structure (5.63%), time (9.01%), feedback (6.25%) and student activity (9.49%). The sub-factors regarding learning materials are perceptual distinguishability (7.22%), conceptual sorting (3.95%) and semantic association (3.98%). Student activity is most important factor of all the factors regarding learners.

The findings in Table 7 make one conclude that intelligence becomes prominent according to all criteria when examining global weights. The outcomes also reveal that it needs to address the criteria concerning learners for a successful learning. In addition to this, high weighted criteria such as student activity and time should be considered for a successful learning.

DISCUSSION

Many studies (Bozkurt 2013; Chang and Chang 2013; Gokalp and Kirbulut 2013; Savas et al. 2013; Tseng and Kuo 2013; Cakir 2014; Dos 2014; Mabatha et al. 2014; Yigit and Ince 2014; Karademir 2015) have been conducted with reference to the factors, which affect learning. The weights of the factors, which affect learning, were investigated in this paper. This study aims to illustrate a gap in the literature while contributing to the literature. It is seen that the papers are inadequate in terms of explaining the importance on learning in all of the studies mentioned above. In other studies, learning is partially handled by only using some of these factors with-

Table 7: Global weights of factors

Main factors	*Ratio (%)*	*Sub-factors*	*Ratio (%)*	*Global weights (%)*
Learners	54.48	Species-specific behavior	6.55	3.57
		Maturation	5.56	3.03
		Motive	16.75	9.13
		General stimulated state	15.27	8.32
		Transfer	13.14	7.16
		Attention	14.16	7.71
		Age	5.40	2.94
		Intelligence	23.17	12.62
Learning Methods	30.38	Topic structure	18.53	5.63
		Time	29.67	9.01
		Feedback	20.57	6.25
		Student activity	31.22	9.49
Learning Materials	15.14	perceptual distinguishability	47.68	7.22
		Conceptual sorting	26.07	3.95
		Semantic association	26.26	3.98

out weighting. For example, the effect of learning materials is examined by Cakir (2014), Dos (2014) and Yigit and Ince (2014). Thefactors affecting computer learning are determined by factor analysis. Data was collected using a survey (Grover et al. 2016). The relationship of the factors affecting nursing education in healthcare unitis examined. For this multivariate analysis, the variance and covariance (MANCOVA) method is applied for data collected from students (Bos et al. 2016). The elements that influence learning for nursing education are considered by qualitative methods, which is group interview and content analysis (Haraldseid et al. 2015). The factors affecting learning for students are handled by multiple regression analysis (Kanthawongs and Kanthawongs 2013). The factors determining web based learning system of workers in automotive factory are evaluated by structural equation model (SEM) method (Karaali et al. 2011). Similarly, the elements influencing the learning of higher education students are analyzed through the SEM method (Merhi 2015).

In this study, the factors that affect learning were analyzed from a holistic viewpoint, dissimilar to current studies. In addition, the studies conducted in the past did not evaluate criteria numerically. They ignored the possibility of weighting the criteria. So, criteria have been subjectively evaluated. In addition this, the consistency ratio was also calculated in this study in order to validate the consistent of the pairwise comparisons. Thus, the weights of criteria that affect learning are determined using the fuzzy AHP method, since this study uses quantitative method, it is different from current studies. Fuzzy logic is also implemented for more realistic outcomes apart from AHP method. Unlike other studies, different disciplines have been applied. Moreover, since the important degree of criteria is specified, strategies based on the weights of criteria can be created different from recent studies.

CONCLUSION

The fuzzy AHP method was implemented for eight experienced primary school teachers in Kocaeli in order to determine the weight of the factors that they believe have impressions on learning. The results of the research conclude that the factors regarding learners are more significant than the other two main aspects. Intelligence is the most significant sub-factor in all sub-factors. Student activity follows intelligence in terms of importance. On the other hand, maturation and age are the two least significant sub-factors within all sub-factors.

It is believed that students can have a better learning experience if mind developing activities for them are increased, since intelligence is the most significant factor. It has been observed that the fuzzy AHP is a method, which can be used to determine the weighting of the criteria and hence their importance. Besides, it can also be used to rank the alternatives. Benefits, reading, writing, narration, description and listening should be implemented as student activities. In addition, motivation of students should also be increased. Since the teachers know the weighting of the criteria with reference to learning, they can prioritize these criteria. They can develop their plans based on these. In this paper, fuzzy

AHP leads to different results from other studies. Fuzzy AHP prevents to subjective evaluations for the factors. Consequently, the development of learning contributes to the development of the education system through correct prioritization. Therefore, fuzzy AHP contributes to anthropology, which is a human science, through the development of education system.

RECOMMENDATIONS

This study focused on the factors that affect learning. The fuzzy AHP method was applied for weighting these factors. Different techniques can also be used to weight these factors. Expert use can be increased to evaluate the learning factors. The researchers' view of the factors that affect learning can be widened. In another study, these factors could be examined at the high school level. Although the numbers of teachers used in this study are ideal for a fuzzy AHP study, the number could be increased to determine the weights of the criteria.

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