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BIOLOGY TEACHING THROUGH SELF-REGULATED LEARNING AND COGNITIVE STRUCTURE: AN ANALYSIS OF THE EFFECT OF LEARNING STRATEGIES FOR COGNITIVE DEVELOPMENT VIA LATENT GROWTH MODEL

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Abstract. *This research applied the learning strategies to predict in an effect longitudinal growth of cognitive structure of students in biology. The aim of the research is to assess the effect of activating learning strategies on cognitive structures regarding biology. The research was conducted by using control group design. The sample of research was composed of 60 prospective teachers randomly assigned to the experimental and the control groups. The longitudinal data were collected every 2 weeks and 4 times in total considering the concept maps. The data were quantitatively analysed in terms of the number of concepts, connections and central concepts. Latent growth modelling (LGM) was used to analyse change in cognitive structure over time. The findings suggested that the experimental group did better in cognitive structure than the control group in terms of forming connections and central concepts. Accordingly, teaching students self-regulated learning strategies and providing support in the written material to activate the strategies influence the development of cognitive structure in a positive way in terms of the extent and the integration. Therefore, activation of the use of self-regulated learning strategies in the teaching are thought to contribute to the learning of biology.*

Key words: *biology education, cognitive structure, self-regulated learning, latent growth modelling.*

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Introduction

Studies performed by cognitive psychologists in relation to memory provided the models of memory and fundamental knowledge on the functioning of memory. In parallel with the studies on cognition, the research conducted by Ausubel (1960) was a pioneering in using cognitive approaches in the process of science learning with such ideas as meaningful learning, prior knowledge, and advance organizer. Meaningful learning is considered as structuring the new meaning—as the integration of existing information with what is newly learnt (cognitive structure or mental model; Novak, 2002). In this context, such concepts as conceptual understanding, misconceptions, and cognitive structure have frequently been researched in studies concerning science learning. These mental structures are considered learners' understanding of a topic and the reflection of their experiences. According to Tsai and Huang (2002), cognitive structure considered to be related to processing of information, is the construction of the knowledge representation along with the concepts and their relations in long-term memory. These structures, which are handled as related to information processing, are also thought to be related with self-regulation and problem-solving processes (Lee, Goh, Chia, & Chin, 1996; Tsai & Huang, 2002).

Cognitive Structure

A number of cognitive learning approaches regard mental representations, called schemata, mental model, or networks, as the configured form of knowledge (Kintsch, 1996). In cognitive psychology, information in external stimuli is thought to be organised by propositions and concepts in memory. The network organisation in long-term memory is described as a structure composed of nodes and labelled lines. Whereas nodes are the simplest representations of concepts, labelled lines between two concepts are described as relationships (Ruiz-Primo & Shavelson, 1996; Shavelson & Stanton, 1975). Accordingly, information on learners' memory conforms to the concepts in semantic networks in the long-term memory and as well as the relationships among these concepts (Kintsch, 1996). In a similar study, Ruiz-Primo and Shavelson (1996) pointed out that, according to several cognitive theories, interrelation of concepts is the basic property of information. The terms, such as cognitive structure, knowledge structure, and structural knowledge are used in many studies in this field (Ausubel, 1960; Lee et al., 1996; Novak, 2002; Shavelson, 1972). They generally express the concept of organisation presented in semantic memory. Shavelson & Stanton (1975) described cognitive structure as the concepts in long-term memory and as a hypothetical construct expressing the relationships among these concepts.

Studying Cognitive Structure

Shavelson (1972) reported that, in addition to learning, the content of teaching material and the structure of students' memory have also been studied by cognitive learning theoreticians. Shavelson (1972) used word association to analyse the content structure of learning material and explained a subject in domain teaching; the researcher then examined the similarities among the cognitive structures of learners studying the subject. Tsai and Huang (2002) identified the methods for researching cognitive structures as free word association, controlled word association, tree construction, concept map, and flow map. The researchers stated that these methods made it possible to analyse a cognitive structure through a visual format.

Concept Maps

Concept maps are described depending on cognitive learning theories: as hierarchical and network. Though hierarchical concept maps based on Ausubel's approach to meaningful learning and developed by Novak and Gowin (1984) were possible to research learners' concepts and conceptual associations in a specific field, networks based on association theory are not hierarchical. They show nodes characterising cognitive structures and arrows between them. Concepts (nodes) are connected to other concepts, with arrows labelled as lines in this approach. Propositions are thus created. Here, concepts are described by their relationships with other concepts, and it is possible for subsets and crosslinks between these concepts to be formed in the networks (Ruiz-Primo & Shavelson, 1996). It is possible to collect data through concept maps about "extent" (that is, the number of concepts), "correctness" (that is, alternative concepts and wrong concepts), and "integration" (that is, the connectedness of the concepts), which are the variables of cognitive structure and related to connections (Tsai & Huang, 2002). Concept map–used as a teaching method, an evaluation tool, and a tool for data collection by most researchers–are analysed in different ways. Qualitative and quantitative analysis are two research methods used here.

Ruiz-Primo and Shavelson (1996) described the issue after conducting a comprehensive literature. The researchers examined three dimensions (task, response, and scoring) together to evaluate concept maps. Here, the scoring system is considered a careful, accurate, and consistent evaluation of concept maps. Scoring components of the map, using criteria map, and combing the two were argued in the same study. Components such as propositions, hierarchy levels, examples, and crosslinks were used in the evaluation of the system to score components of the map. The technique used in evaluating network concept maps according to this approach is graph measurement theory (Friege & Lind, 2000). Using this technique, the concepts, associations, and organization stored in semantic memory can be represented in graphs and digitized. A description of the concept maps called graphs is determined through five different graph criteria independent from each other: the number of concepts, the number of lines (arrows), the number of central concepts, the number of components (subsets), and the number of unrelated concepts. Friege and Lind (2000), on the other hand, evaluated the concept maps quantitatively through such variables as the number of concepts, the number of connections, and the number of central concepts. The number of central concepts is defined as the concepts associated with more than three concepts. One of the methods recommended for qualitative evaluation is classification based on the properties of the concept map. Three types were suggested by Kinchen, Hay and Adams (2000) for use in the evaluation of the qualitative evaluation of the concept maps—namely, the spoke, chain, and net types.

Teaching Biology, Self-regulated Learning and Cognitive Structure

Biology and its sub-branches contain a great number of concepts and relationships among them. Mintzes, Wandersee, and Novak (2001) found that biological knowledge is in an integrated structure in the form of a network

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and kept in memory with the help of concepts; accordingly, the fact that knowledge from different sources turns into conceptual understanding in different ways is considered the nature of biological knowledge. Biology is full of concepts, which inherently increase the importance of the concept of teaching in biology education. Researchers in the field of biology education have examined learners' cognitive structures (Bahar, M., Johnston, & Sutcliffe, 1999). In this framework, the concepts of enzyme, protein, gene, and other genetic topics as well as blood and blood circulation (Chang, 2007) and photosynthesis (Ross, Tronson, & Ritchie, 2005) are examined; concept maps, drawings, and free word association used as the methods of research.

Self-regulated learning is defined as a way of learning in which learners regulate the learning process by belonging to them and being produced by them (Landmann, Perels, Otto, & Schmitz, 2009). Hence, learning strategies regarded as the structural elements constituting learning through self-regulation are considered to be in the centre of self-regulation models and closely related to information processing (Artelt, 2000; Boekaerts, 1999). Learning strategy is defined as the whole of procedures aiming to gain new knowledge and directed to cognitive, behavioural purposes in information processing (Hasselhorn & Gold, 2006; Weinstein & Mayer, 1986). Cognitive structure, on the other hand, includes learners' knowledge and experiences to which they refer in processing information (Tsai & Huang, 2002). Likewise, a bad cognitive structure results in learners' having a bad information processing and failing to acquire the new knowledge (Tsai & Huang, 2002). In addition, according to the comprehension theory (Kintsch, 1996), learners' learning strategies in addition to the properties of texts are also influential in learning by means of oral and written texts. This situation has been explained by dynamic model of mind and is associated with cognitive structure (Schnotz, 1994).

Although there are many separate studies on learning strategies, cognitive structure, and biology instruction, it is not possible to figure out the effect of using its learning strategies on forming students' biological knowledge based from these studies. It is not known whether the use of learning strategies will turn out to be effective in supporting cognitive structure. Although previous researches, related on misconceptions, alternative concepts and students' concepts in biology (Hazel & Prosser 1994; Tekkaya 2002; Temelli, 2006) have focused on the outcome of learning, these are not concerned with the process of acquisition of knowledge. However, the review of literature provides theoretical evidence that learning strategies are effective tools for facilitating learning and forming student knowledge in biology education. This research has signalled a greater understanding on relation between the use of learning strategies and the construction of knowledge structure of learners. We also believe that when we inform the students about learning strategies, and support activating learning strategies during reading field texts, the effect of the learning strategies on cognitive structures can occur. The present paper focuses on the close theoretical relationships among self-regulated learning strategies, the means of information processing, and the development of biological knowledge as cognitive structure. Thus, it is believed that learners' knowledge in appropriate learning strategies when studying biology and working with the materials to activate their use of the strategies will be effective in development of cognitive structures proper to biology. The aim of the research is to test the effect of using learning strategies on the cognitive structure in the biology learning. In the research such variables are examined as the number of concepts, connections and central concepts related to the cognitive structure. In order to test the effect on the cognitive structure variables use in learning strategies, two groups are formed. One of these groups has been informed of self-regulated learning strategies and has been provided with lecture notes supporting the use of these strategies. Thus, the research questions are formulated as follows:

- Does between groups have significant difference over the time according to the number of concepts?
- Does between groups have significant difference over the time according to the number of connections?
- Does between groups have significant difference over the time according to the number of central concepts?

Methodology of Research

The design of this research, which was set out to research the effects of self-regulated learning strategies applications on the variables of cognitive structure, is shown in Table 1. Accordingly, the implementation processes of the experimental and the control groups were designed as teaching with using learning strategies support (X) and as teaching without this support (Y), and throughout the application process, four measurements (O) were done in the same way and about the same issue. The participants (n) were determined through random appointment (R) - which is generally true for experimental designs.

Table 1. Research design.

Application	Group	n	Time 1		Time 2		Time 3		Time4	
			Application	Measurement	Application	Measurement	Application	Measurement	Application	Measurement
Teaching with activation of using learning strategies support	Experimental	R	X	O1	X	O2	X	O3	X	O4
Traditional practice	Control	R	Y	O1	Y	O2	Y	O3	Y	O4

Measurements were performed in the two separate groups for more than two variables at different times in this research. Therefore, this longitudinal data collected research is also a quasi-experimental research (Gall, Borg, & Gall, 2007).

Sample

The research was performed in a state university with 80 prospective teachers being from the Elementary School Teaching Department in the first academic year. Sixty of them without record of absenteeism through the end of the study were included in the research sample. Among them, 23 were female students and 37 male. Their grade point averages ranged between 1.24 and 3.60 in that academic year, and the average for academic achievement was 2.69 for the group. These students graduated from similar types of high school and have taken compulsory biology course at the university. The experimental and the control groups were formed by listing the students' names in alphabetical order. Therefore, the participants were determined through random appointment, which was generally true for experimental designs. Sample size for structural equation modelling (SEM) is an important issue. Small sample sizes (fewer than 100) were accepted very limited in terms of power of statistical tests. Nevertheless, the range of sample sizes for different studies was reported from 40 to 8650 in literature (Kline, 2005; p.15).

Procedure

In line with research design employed, data were collected according to the plan shown in Table 2. Prior to the research, prospective teachers were instructed on concept maps and practiced creating concept maps in the form of network without giving any concepts. Two hours of instruction were offered to the experimental group to inform students of learning strategies in a separate session. The informational session was based on Mandl & Friedrich (2006) study and in accordance with the classification reported by Tasci & Soran (2012). Accordingly, the cognitive and metacognitive learning strategies as well as the learning techniques in those strategies were described and explained to the participants of the experimental group. The implementation stage lasted for 8 weeks total, and participants were asked to prepare concept maps on organic compounds and cells at four different times.

Table 2. Research process.

	Control group	Experimental group
Prior to application	Instruction on concept maps (2 hours)	Instruction on concept maps (2 hours) Introduction of the learning strategies (2 hours)
Application	Performing the teaching in the classroom (16 hours) Lecture notes_ classical teaching materials Creating concept maps (At 4 different times)	Performing the teaching in the classroom (16 hours) Lecture notes_ activating support learning strategies Creating concept maps (At 4 different times)

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Both groups were given lecture notes initially, and teacher-centred teaching was performed using the blackboard and the projector. The teaching was conducted by the researcher in relation to the General Biology course. The teaching did not involve any types of experiments. Experimental and control group students were equally provided with a period of education on the subject of biology and on making concept maps, as shown in Table 2. As different, participants in the experimental group were offered two hours seminar on learning strategies, of which effects were analysed; the control group was not offered a seminar, and the lecture notes handed out to the prospective teachers differed.

Lecture note for the control group. Control group students were given plain texts with titles, sub-headings and explanations under them. It covered six pages total. The text wrote Times New Romans and 12 points, and its headings were bold. The information content and formatting of text were equal to the text for experimental group.

Lecture note for the experimental group. The lecture note covered eight pages total, and has two columns page-construct. It included information of subject, organic molecules and cell, and questions, warnings, guidance, which provide activation of learning strategies. The warnings were mostly for planning strategies initially. For this reason, the statement "you should think about how to study in order to understand the subject" was included in the beginning while the statement "determine the concepts that you know in the topic" was used for the distinguishing strategies to support comprehension. The text was supported by applications for organizing the subject matter and determining the concepts. For these purposes, sub-headings were required, and applications such as completing the diagrams and remembering the concepts were also included in the form of "do you remember the concepts?" and then "what is an organic molecule?", which were asked directly for the definition. At the end of the topic, attempts were made to activate the control strategies as in the statements "check your learning.", "Therefore, try to remember the knowledge and the concepts by asking yourself questions."

Data Collection and Evaluation

The data used to answer the research question was collected through concept maps structured in the form of network without giving any concepts in the application part. Criteria from graph measurement theory (Friege & Lind, 2000) were used. Their definitions and the relevant abbreviations are shown in Table 3.

Table 3. Graph measurement theory.

Graph measurement	Symbol	Definition
Number of concepts	CN	Number of concepts
Number of connections	CoN	The number of arrows used in relating
Number of central concepts	Ce	Concepts with three or more connections

The number of concepts, connections, and central concepts were used for quantitative analyses in the research. The criteria for which the definitions were presented were counted by two different researchers, and the average was used for the reliability of the data. As the averages found for the rates were used in the research, the reliability coefficients were derived from the Pearson correlation coefficient though the Spearman-Brown prophecy formula (Crocer & Algina, 1986; p.137). In this way, the reliability coefficient was found 0.99.

Data Collection for the Initial Properties of Participants

Students' learning strategies and their academic achievement in terms of the research problem were important in order to provide the internal validity of the research.Therefore, the research involved identifying the initial properties of the groups for these relevant variables. Hence, grade point averages were obtained for the experimental and control groups for the academic year in which the research was conducted, and Motivation and Learning Strategies Scale (MSLQ-TR) were administered to the participants in order to determine their use of learning strategies.

The Motivation and Learning Strategies Scale (MSLQ-TR), developed by Pintrich, Smith, Garcia, & McKeachie (1993) and adapted into Turkish by Büyüköztürk, Akgün, Özkahveci, & Demirel (2004), was used for the evaluation of the students in terms of learning strategies. The scale with a nine-factor structure contained motivation and learning strategy sub-scales. The total score for the learning strategy sub-scale was used in this research, and the differences between the experimental and the control groups according to these variables were researched.

Data Analysis

Longitudinal data is analysed with latent growth model. This is a model, which is from the family of SEM, to investigate longitudinal growth in a variable (Duncan & Duncan, 2004). Aşkar and Yurdugül (2009) pointed out that LGM is a structural approach which reveals the development of the data obtained at different times in the research concerning the development of learning. Types of LGM were named variously. Preacher, Wichman, MacCallum, and Briggs (2008) indicated that two main types of LGM were unconditional LGM and conditional LGM. In order to examine group differences over time there are two ways: 1) splitting the sample (multi-groups model) and 2) specifying the grouping variable (conditional LGM). The analysis of using learning strategies affecting differences in intercept and slope can be considerably simplified by including group as an exogenous predictor (time invariant covariate) both intercept and slope in a single-group analysis. Using LGM basic model was tested with conditional LGM. Conditional LGM makes possible to research the source of change. The use of a group variable as a predictor was demonstrated in Figure 1.

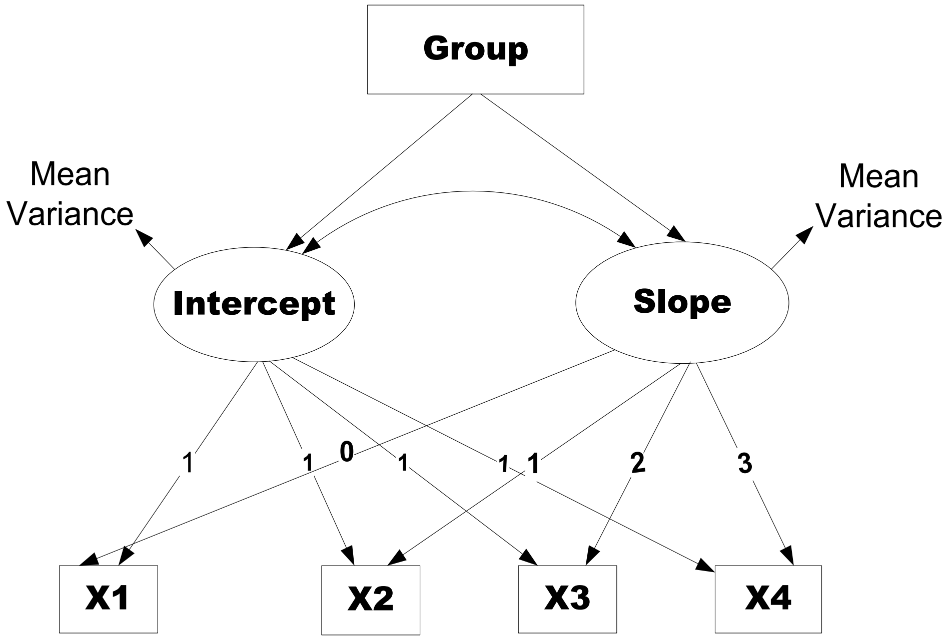

Figure 1: Structural equation model (SEM) diagram of conditional LGM with four time points.

The LGM parameters are explained according to this model. The measurements for the latent variables (described as intercepts and slope), the conditional variable (described as group), and the cognitive structure variables (drawn as X1, X2, X3, and X4) are shown in the model in Figure 1. The intercept mean represents the average for students' prior achievement, whereas the variance intercept shows the homogeneity of the group. The slope mean represents the average change in the cognitive structure variables in each measurement, while the slope variance represents the change in the increase. The intercept and slope covariance, on the other hand, show the relationship between the initial cognitive structure and the change in the cognitive structure. The effects of the experimental operation on the change in the cognitive structure are shown with the group variable in the model. The parameter values calculated here show which group benefits from the change. Because the experimental group was encoded as 0 and the control group as 1, the negative result derived was interpreted in favour of the experimental group. For the model-data fit indices, in the LGM estimation, more than one index was checked instead of one index based on the literature concerning the test of model fit suggested and the decision was made on the index values acceptable by Hu & Bentler (1999) for SEM.

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The status of the groups in terms of initial properties were analysed through the one way MANOVA. The groups were compared in terms of dependent variables by conducting one way MANOVA in order to avoid Type I error in data analysis. The normal distribution of the data set was examined by drawing Q-Q plots. It was decided by the expert opinion and comparing Q-Q plot for normal sample (Howell, 2013, p. 76) that the number of observations in the groups and the distribution were appropriate for the analysis (Tabachnick & Fidell, 2013, p. 253). The result of data analysis has also shown that equality of covariance matrices (Box 'M – value = 1.431; F(3) = 0.458; p = .711) is appropriate.

Results of Research

Initial Properties

The status of the groups in terms of these variables before the application were analysed through the one way MANOVA; the results are shown in Table 4.

Table 4. Tests of between-subjects effects.

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Observed Power[b]
Corrected Model	MSLQ_ Score	,455a	1	0,455	3,598	0,063	0,06	0,462
	Academic Average	,081c	1	0,081	0,317	0,575	0,006	0,086
Intercept	MSLQ_ Score	845,527	1	845,527	6688,461	0	0,992	1
	Academic Average	420,673	1	420,673	1647,867	0	0,967	1
Group	MSLQ_ Score	0,455	1	0,455	3,598	0,063	0,06	0,462
	Academic Average	0,081	1	0,081	0,317	0,575	0,006	0,086
Error	MSLQ_ Score	7,079	56	0,126				
	Academic Average	14,296	56	0,255				
Total	MSLQ_ Score	855,422	58					
	Academic Average	435,147	58					
Corrected Total	MSLQ_ Score	7,534	57					
	Academic Average	14,377	57					

a. R Squared = ,060 (Adjusted R Squared = ,044); b. Computed using alpha = ,05; c. R Squared = ,006 (Adjusted R Squared = -,012)

As the table shows, no statistically significant differences exist between the experimental group and the control group in terms of the general academic grade point averages (F(1, 58)= 0.317, p> .05, $\eta^2 = .006$) and learning strategies (F(1, 58)= 3.598, p> .05, $\eta^2 = .06$). In addition, Wilks' Lambda value is near to one and insignificant according to findings of multivariate tests (Wilks' Lambda Value = 0.93; p>0.05). This result supports the finding of Table 4 that there are no significant differences between groups.

Students' Cognitive Structure

Cognitive development was evaluated separately through conditional growth curve model for the number of concepts, connections, and central concepts analysed as the variety of cognitive structure in this research. Descriptive statistics and correlations for the variables utilized in the latent growth models are shown in Table 5.

Table 5. Descriptive statistics and correlation for the observed variables utilized in the LGM.

	CN_ T1	CoN_ T1	Ce_ T1	CN_ T2	CoN_ T2	Ce_ T2	CN_T3	CoN_ T3	Ce_ T3	CN_ T4	CoN_ T4	Ce_ T4
CN_T1	1											
CoN_T1	0,30*	1										
Ce_T1	0,08	0,49*	1									
CN_T2	0,25	-0,24	0,08	1								
CoN_T2	-0,11	0,04	0,27*	0,55*	1							
Ce_T2	-0,14	-0,06	0,23	0,41*	0,75*	1						
CN_T3	0,32*	-0,12	0,04	0,74*	0,36*	0,28*	1					
CoN_T3	0,06	0,14	0,23	0,50*	0,62*	0,47*	0,49*	1				
Ce_T3	-0,14	-0,20	0,17	0,57*	0,59*	0,58*	0,51*	0,73*	1			
CN_T4	0,06	-0,17	0,06	0,68*	0,58*	0,46*	0,71*	0,56*	0,72*	1		
CoN_T4	-0,13	-0,20	0,12	0,53*	0,60*	0,51*	0,44*	0,46*	0,73*	0,77*	1	
Ce_T4	-0,20	-0,25	0,09	0,60*	0,71*	0,59*	0,44*	0,57*	0,80*	0,79*	0,85*	1
Mean	12,75	6,58	0,83	23,07	13,75	2,40	32,25	21,50	3,72	56,82	35,37	6,75
Std. Dev.	6,74	5,25	0,81	10,12	8,42	2,26	15,92	11,48	3,21	27,27	21,58	4,95
Skewness	1,39	0,56	0,72	0,21	0,51	0,93	0,69	0,39	0,73	0,66	0,85	0,86
Kurtosis	2,53	-0,38	0,04	-0,57	-0,15	0,15	0,08	-0,78	-0,47	0,17	0,18	0,39
N	60	60	60	60	60	60	60	60	60	60	60	60

**Denotes correlations significant at p<0.05.*

Whether or not the experimental practice was meaningful was tested through conditional LGM. The fit indices for the models are shown in Table 6.

Table 6. Model-data indices for the cognitive structure variables of the LGM.

Conditional LGM	GFI (>0,90)	CFI (>0,90)	NNFI (>0,90)	RMESA (<0,08)	Chi-Square/df (<3)
Concepts	0,95	0,96	0,99	0,047	2,43
Connections	0,95	0,98	0,95	0,091	1,53
Central concepts	0,99	1,00	1,00	0,00	0,33

According to the Table, the fit indices for this models were found for concepts (Chi-Square (4; N=60) =9,73, p=0.045), connection (Chi-Square (5; N=60)=7.64, p=0.018), central concept (Chi-Square (6; N=60) = 1.98, p=0.018) to be at the perfect level of fit. It may be said that the model-data fit is acceptable. Initially, conditional latent growth models were estimated to determine growth that existed parameters of the three variables of cognitive structure (concepts, connection, central concept). The parameters are shown in Table 7. The estimated parameters indicated that mean of intercepts significant in each variable, concept and connection, and central concept were significant. Conversely, the variance of intercept parameters was insignificant for each variable, concept, connection, the central concept. According to these findings, it may be said that participants have prior cognitive structure in terms of the number of concepts, connections and central concepts, however, differences among initial cognitive structure of participants are not significant.

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Table 7. Conditional latent growth curve model estimated parameters.

Parameter	Estimate (SE)	t value
Concepts		
Mean of Intercept	12,84 (0,78)	16,48*
Variance of Intercept	-7,74 (11,88)	0,66
Mean of Slope	9,88 (0,96)	10,32*
Variance of Slope	30,52 (8,66)	3,55*
Group effect on intercept	4,48 (1,64)	2,74*
Group effect on slope	-10,24 (1,84)	-5,56*
İntercept/Slope covariance	20,06 (12,36)	1,62
Connections		
Mean of Intercept	6,49(0,62)	10,48*
Variance of Intercept	-5,21(9,16)	0,53
Mean of Slope	7,52(0,75)	10,00*
Variance of Slope	21,63(9,08)	2,38*
Group effect on intercept	5,24(1,15)	4,55*
Group effect on slope	-11,39(1,38)	8,26*
İntercept/Slope covariance	6,79(6,30)	1,08
Central concepts		
Mean of Intercept	0,83(0,10)	7,92*
Variance of Intercept	0,45(0,24)	1,90
Mean of Slope	1,52(0,19)	7,99*
Variance of Slope	1,52(0,34)	4,46*
Group effect on intercept	0,076(0,21)	0,36
Group effect on slope	-2,26(0,26)	-8,58*
İntercept/Slope covariance	-0,01(0,15)	-0,08

**denote $t > 1.96$, $p < 0.05$*

On the other hand, according to mean of slope parameters for the fourth time points were significant growth, in concept, in connection, and in the central concept. Variances of the slopes were significant for concept, connection, and central concept. These findings indicate that significant individual variations existed in the development of the cognitive structure variables. On the other hand, in the Table 7, it is shown that the parameter correlations between intercepts and slopes (intercept/Slope covariance) for each three cognitive structures are insignificant. This finding reveals that the initial statuses of cognitive structure variables were not related. One remarkable finding was that the students are not homogeneous in terms of the rate of growth in their cognitive structure.

Group effect on intercept of the model estimations shown in Table 7 are significant and positive for concepts and connections, whereas it is not significant for central concepts. The results for models showed that the coefficients for predicting intercept from group were 5.24 (connection) and 4.48 (concept); that is the control group (coded 1) has higher average scores than experimental group (coded 0), and they were significant. However, the coefficients for central concept were not significant. The effect of group effect on slopes were significant and negative in terms of concepts, connections, and central concepts. Accordingly, control group also showed less change over time than experimental group, which is significant. Thus, due to the support of self-regulated learning strategy given to the experimental group, the change in the cognitive structure was more effective in this group than the one in the group without support.

Discussion

The estimates from the conditional LGC model reported in Table 7 provide an understanding of the longitudinal changes in cognitive structure. First, there was not significant variability in the individual intercepts at the initial time; that is, the participants were homogeneous in terms of cognitive structure variables according to the variance of intercept. Second, there was a significant change in the amount of number of concepts, connections, and central concepts reported over the 8-week period. In the other words, significant development occurred in the cognitive structure in treatment process for both groups. Third, at the group level, there was significant variability in the increase of concepts, connections, and central concepts. Treating time invariant covariates (group) as predictors of growth factor can be understood mediation, which has the effect of the time invariant covariate on the outcome variables (Preacher et. al., 2008). Accordingly, differences emerged between the groups. Here, the group variable was created based on informing the students of self-regulated learning and the support of activating the learning strategies provided in the teaching note. Therefore, self-regulated learning applications were found to be a significant predictor of cognitive development. These findings indicate that the learning strategies are influential in the formation of the connectedness and the central concepts in cognitive structure. Considering the content of the experimental application, it is clear that informing the students of the learning strategies and supporting the activation of those strategies in the lecture notes have significant effects on the change over time of the cognitive structure, especially in terms of central concepts and connections. Accordingly, teaching students self-regulated learning strategies and providing support in the written material to activate the strategies influence the development of cognitive structure in a positive way in terms of the extent and the integration as defined by Tsai and Huang (2002).

These findings concur with those from previous research studies, especially in terms of the theoretical framework. The correlations between the process of information processing and the development of cognitive structure are remarkable in Tsai and Huang (2002) and, in a similar study, the comprehension model established by Schnotz (1994) calls attention to the correlations between learning strategies and cognitive structure. Accordingly, it is pointed out in the comprehension theory (Kintsch, 1996) that learners' learning strategies beside the properties of texts are also influential in learning from oral and written texts. This situation is explained with the dynamic model of mind, and is made associated with cognitive structure (Schotz 1996). On reviewing the studies concerning good information processing or concerning good strategy use, it is found that cognitive structure and the use of strategy are considered to be related in the context of prior knowledge, and that they are made prominent (Pressley, Borkowski, & Schneider, 1989). Furthermore, the activation of prior knowledge and the evaluation strategies are considered to be directly effective in relating the gained knowledge to the new knowledge (Mandl & Friedrich, 2006). It is also reported in studies concerning biology education that evaluation and metacognitive strategies are influential in students' concepts, the number of connections, and their conceptual understanding Harms and Gonzalez-Weil (2003) reported that relationships in the same direction are available between students' metacognitive levels due to the conceptual development they have undergone with regard to the topic of cells. Labuhn, Bögelholz, and Hasselhorn (2008) reported that the self-regulating learning strategies' applications integrated into the seventh-grade biology course supported students' studies and provided long-term advantages in the field related tests. Tasci and Soran (2012) identified the types of learning strategies used by students. The types differ, especially in terms of employing the evaluation strategies, but the type using an advanced strategy focuses more on the concepts in the learning process; its cognitive structure also differs from those of the other types in terms of central concepts. Similarly, according to Hilbert and Renkl (2008), students form concept maps based on the type of their learning strategies. Such findings demonstrate that the students using good strategies have a higher number of concepts and associations.

In summary, this research found that significant differences between groups occur over time in terms of the variables of cognitive structure in consequence of using learning strategies. It is argued that activating the use of learning strategies remains useful from which to explain the change of cognitive structure.

Conclusions

To conclude, by developing learners' properties in this direction, learning strategies can become a factor raising learners' achievement in terms of cognitive development. Therefore, designs of printed materials and digital media to activate the use of self-regulated learning strategies are thought to contribute to the field. The usual lecture

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notes do not encourage students in terms of self-regulation. Instead of authors printing the concepts considered to be important in italics or in bold, it would be more effective for the integrity of cognitive structure to lead the readers to determine the important concepts and the concepts that they know and the ones they do not know and to make them question how much they have learnt at the end of the reading.

Self-regulated learning and the teaching of learning strategies for learners systematically, as well as the designs supporting the use of them, should be researched from diverse perspectives. Promoting learners' proficiency when using metacognitive learning strategies and evaluation strategies will ensure that cognitive development occurs in the form of network.

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