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A Factor Effecting Students' Performance in Biology: Working Memory Capacity

Biyolojide Öğrencilerin Başarısını Etkileyen Bir Faktör: Çalışma Hafızası Kapasitesi

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Abstract
Several studies in information processing would seem to suggest that, when the information is admitted through the perceptive filter, it passes into a working memory where it is held and manipulated before being rejected or passed on to long-term memory. One of the most important characteristics of this area is its being a limited space. In this research, the effect of students' working memory capacity (WMC) on their performance in general biology was studied and 150 primary school teacher candidates were involved. Digit span backwards test (DSBT) was used to measure the students' WMC. A knowledge test which consisted of multiple choice items, in which the response has to be justified, was developed to assess the degree of understanding in biological concepts. As a result, a statistically significant positive correlation (r= 0.411) was found between students' scores in knowledge test and DSBT. In addition, the relationship between the size of WMC and the questions that had the lowest facility values in knowledge test was sought and the implications of the results for teaching and learning are discussed.
Key Words: Working Memory Capacity, Biology

Öz
Bilgi İşlem alanında yapılan çeşitli çalışmalar, algı süzgecinden geçebilen uyanların Uzun Dönemli Hafızaya aktarılmadan önce Çalışma Hafızası alanında tutulduğunu, işlem yapıldığını ve organize edilip şekillendirildiğini ileri sürer. Bu alanın en önemli özelliklerinden birisi sınırlı bir kapasitesinin olmasıdır. Bu çalışmada, çalışma hafızası kapasitesinin genel biyoloji ders başarısına etkisi araştırılmıştır. Araştırma bu dersi alan 150 Sınıf öğretmeni adayı üzerinde yapılmıştır. Öğrencilerin çalışma hafızası kapasitelerini ölçmek için Sayı Zinciri Geri Bildirim Testi kullanılmıştır. Ders başarısını ölçmek amacı ile verilen cevabın mantıksal sebebinin de açıklanması gereken çoktan seçmeli bir bilgi testi uygulanmıştır. Sonuç olarak; öğrencilerin bilgi test puanları ve sayı zinciri geri bildirim test puanları arasında anlamlı bir ilişki (r=0.411) bulunmuştur. Ayrıca bilgi testindeki kolaylık değeri en düşük sorular ile hafıza kapasitesi arasındaki ilişkiye de bakılmış, sonuçların öğrenme ve öğretmeye etkisi tartışılmıştır.
Anahtar Sözcükler: Çalışma Hafızası Kapasitesi, Biyoloji

Introduction

There are several factors that effect the students' performance in any topic; these are i) the factors related to students such as prior knowledge, socio-economic situation, learning style, interest and motivation, ii) the factors related to teachers such as teaching style, teacher sympathy, proficiency in study area, iii) and other factors such as the variability in assessment tools, physical conditions of the class, language and terminology, effective use of technological equipments. Working Memory Capacity (WMC) is one of these factors, and several studies indicate that it effects students' performance in scientific disciplines, especially in chemistry (Johnstone, Sleet and Vianna, 1994; Johnstone and El-Banna, 1986), and in physics (Johnstone, Hogg and Ziane, 1993). However, there is no study in terms of the WMC effect on students' performance in biological concepts, and the concept of working memory capacity is fairly new in Turkey.

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The purposes of this study are; i) to assess the WMC of the students and to classify them into their WMC, ii) find out the relationship between the capacity of working memory and student success in general biology course, and, iii) to determine the success of students having different WMC in the questions that has the lowest facility values.

Many studies in information processing would seem to suggest that when the stimuli and the information are admitted through the perceptive filter they pass in to a WM where it is held and manipulated before being rejected or passed on to long-term memory (LTM). In the literature, the terms working memory (Johnstone, 1997; Baddeley, 1986) and short term memory (Case, 1985; Atkinson and Shiffrin, 1968) are used interchangeably. If someone has been asked to memorize a set of numbers such as a new telephone number, he recalls them back in the same order within seconds. In this case there is no processing (i.e. working on function), the space is used completely as a short term memory. However, in another case, if someone receives input in the form of numbers and if he is asked to sum the first and the last and then multiply the result by the middle number, a working process begins to operate and the space called in this case is WM (Johnstone, 1988, 4).

There are two important functions of the WM. These can be listed as:

i) it is the conscious part of the mind that holds ideas and facts while it thinks about them. It is a shared holding and thinking space where new information coming through the perceptive filter consciously interacts with itself and with information drawn from the LTM to make sense.
ii) it is a limited shared space in which there is a trade off between what has to be held in conscious memory, and the processing activities are required to handle it, transform it, manipulate it and get it ready for storage in LTM store. If there is too much to hold, there is not enough space for processing; i.e., if a lot of processing is required, it cannot hold much (Johnstone, 1997, 847). Several studies imply that the capacity of the WM is around seven items, and probably not more than nine items. These estimates are often summarized by the statement that 7 plus-or-minus 2 items of information can be stored or can be held in the WM (or short term memory) space (Miller, 1956). There are a number of tests (e.g., digit span test, digit span backwards test, figure intersection test) to measure the capacity of WM. The information about these tests will be given below.

Method

Sample

The sample of this study consists of 150 first-year students who were studying in the department of elementary education. The number of girls and boys in the sample are almost equal (70 boys and 80 girls).

Test to measure the Working Memory Capacity (WMC)

For many years, WMC was measured by using a digit span task, in which subjects are read a series of digits (e.g., 6 2 0) and immediately asked to repeat them back. If the subjects do this successfully, they are given a slightly longer list (e.g., 6 2 0 5 9) and so on. This task draws directly on short term memory; the mistakes should begin to appear when there is more on the list than the memory can hold.

In this study researcher used a test which involved holding, translating and rearranging. It is called Digit Span Backwards Test (DSBT). This test was developed and modified at the Centre for Science Education in the University of Glasgow and has been used by several researchers (e.g., Bahar and Hansell, 2000; Su, 1991; Johnstone and El-Banna, 1986), and its validity and reliability has already been established. In this test, students were given a date in words, for example 'Twenty third November' and were asked to convert the date into digits (2 3 1 1) and arrange them in numerical order from the smallest to the largest (1 1 2 3). This had to be done entirely in the head. Then students were given a slightly longer date. A total of 12 dates were included in this test, each date was shown on the overhead projector. The smallest date in the test consisted of 3 digits and the largest date consisted of 8 digits. The time given was proportional to the number of digits in each date, for instance, for the date 'Twenty third November' students were given four seconds, because there are four digits.

For the scoring of the students the DSBT, the highest number of digits that a student was able to recall correctly in the order was considered to be the size of his working memory. After collecting all responses, three groups of students were classified: those giving the correct order of 3, 4 and 5 were considered as having Low Working Memory Capacity (LWM), while those giving the correct order of 7 or 8 digits as having High Working Memory Capacity (HWM) and giving the correct order of 6 digits as having Medium Working Memory Capacity (MWM). For this classification, the work done by Bahar and Hansell (2000) was adopted.

Knowledge Test

A knowledge test was prepared to measure the students' level in biological concepts that had been given during semester. The test consists of 20 multiple choice questions in which the response has to be justified. The logical reason behind the students' response was required in the multiple choice question in order to reveal whether they chose the right option by guessing or not. The responses of the students that were not justified were not considered in this study.

The demand of each question in the knowledge test was determined by three lecturers who were teaching biology. Total point in the test was 60.

To reveal the relationship between the WMC and students' performance in the knowledge test, the students' scores in the DSBT and their scores in the knowledge tests were plotted against each other. In order to determine the success of students having different WMC in the questions that has lowest facility values (FV), the facility value (i.e. the average students' success rate for each question) of each question was calculated. The mark of students for each question was summed, and this was divided by the possible highest sum of the students' marks to calculate the FV of each question.

Results and Discussion

After getting the responses of the students in the DSBT, three students' groups (i.e. Low -, Medium - and High Working Memory Capacity) were classified. The number of students in these three categories are 68 (45% of the sample) in LWM, 44 (29% of the sample) in MWM and 38 (26% of the sample) in HWM. This result clearly indicates that nearly half of the sample group had scores 3, 4 or 5 in DSBT. The rest scored between 6 and 8.

As indicated in Method section, to reveal the relationship between the working memory capacity and students' performance in the knowledge test, the students' scores in the DSBT and their scores in the knowledge tests were plotted against each other, and a positive correlation emerged ($r= 0.411$ $p=0.01$/2-tailed). On this basis, it can be said that the students who had high working memory capacity had higher scores in the knowledge test than the students who had low working memory capacity.

Facility value (FV) of each question in the knowledge test and the order of the questions from the highest to lowest FV are given in Table 2.

As shown in Table 1, all students correctly answered the questions 3 and 8, hence, these appeared as the easiest questions. These questions require lower levels of thinking that ask for knowledge or comprehension; i.e, skills of analysis and synthesis are not required. Therefore, solving steps for these questions are within the capacity of the students who had low working memory capacity. However, the questions 7, 15, 12 and 16 could not be answered correctly by more than half of the students in the sample; and therefore, their facility values are low. Comparing to the easiest questions in the text, these questions require not only knowledge and comprehension but also higher levels of thinking, that is, the skills of analysis and synthesis. These four questions which are the most difficult in the knowledge test and

Table 1
Facility values of each question and their order according to FV

Questions	3	8	20	6	5	18	19	10	4	13
FV	1	1	0.92	0.86	0.84	0.80	0.78	0.74	0.72	0.70
Questions	11	17	9	2	14	1	7	15	12	16
FV	0.68	0.68	0.66	0.62	0.60	0.53	0.44	0.42	0.36	0.30

the number of students who were in different categories in terms of their WMC are given in Table 2. In this study, the students who had medium working memory capacity were not considered because it is thought that looking at both ends of the WMC can give better results in order to see the difference between high and low WMC.

As can be seen in Table 2, the majority of the students who had high working memory capacity successfully answered all four questions. However, there are some students with HWM who were unable to answer these questions. Normally, the difficult questions, which were within the capacity of the students of having HWM, were expected to be solved by these students. However, a misconception in the knowledge network or a misunderstanding about a concept or false strategy for problem solving might have caused failure on the part of these students. The reason behind their performance below their potential might also be related to another psychological factor: the field dependence /independence. Some studies done in chemistry (Johnstone and Al-Naeme, 1991) and in physics (Johnstone et al., 1993) show that field independent students (who can easily break up an organized field and can separate relevant material from its context or can discern signal -what matters- from the noise -the incidental and peripheral- in a confusing background) with a low working memory capacity performed as well as field dependent students (who has difficulty in separating an item from its context) with a high working memory capacity.

Table 2 also reveals that majority of the students who had low working memory capacity could not solve these questions. This is an expected result because if the demand of the question exceeds the capacity of the students, problems are not expected to be solved. However, this does not mean that a student who has a low WMC is unable to solve the problem if it exceeds his memory space. As can be seen from table 2, some students were able to solve the most difficult questions even though they had low WMC. In question 7, twenty percent, in question 15 eighteen percent and in questions 12 and 16 fifteen percent of the students in the LWM group could solve the problems even though the demand of the question exceeds their capacity. This result can be explained by the 'chunking strategies.' The limitation of the WM is on the number of chunks of information that may be stored or retrieved. A chunk is what the observer perceives or recognizes as a unit, for instance, a word, a letter or a digit (Johnstone and Kellet, 1980, 176). By using chunking strategies many pieces of information can be handled as if they were one. For instance, assume that you have to learn a new telephone number which consists of 10 digits (03245156150). This means ten pieces of information have to be remembered. However, you can break down the whole number as 0324-515 6150. 0324 is the 'chunk' for Mersin; 515 is the district and 6150 is the number of the subscriber. So, ten pieces of information can be chunked as three pieces of information. However, it is important to mention that, as chunking largely depends on the previous learning (Johnstone and El-Banna, 1986, 80), the prior knowledge of the students who had LWM might have an effect on their performance in these difficult questions.

The strategies that some students (about 20% of students who had LWM) have developed in biological topics gave them the opportunity of operating well outside their working memory capacity. This also raises the question about how the performance of the other 80% can be improved. Can chunking strategies be taught? Or Can chunking strategies be effected by other psychological factors? These questions might be the subject of further study.

Table 2
The most difficult questions and the number of the students who solved them correctly

Questions	7		15		12		16	
FV	0.44		0.42		0.36		0.30	
WMC	LWM	HWM	LWM	HWM	LWM	HWM	LWM	HWM
N. of students	14	30	12	29	10	25	10	24
and their percentage	20%	79%	18%	76%	15%	66%	15%	63%

Teaching Implications And Suggestions

1. WMC is one of the factors that effects students' performance. Therefore, textbook writers and teachers should take into consideration that WM can be easily overloaded because of its limited capacity. Therefore, the content of the topics should be kept at a minimum and within the capacity of students. The detailed information that is not fundamental should be avoided as understanding the topics or acquiring the concepts meaningfully do not depend on it.
2. To prevent the overloading of WMC of the students who have encountered a topic for the first time, the techniques (e.g., concept maps, spider maps etc.) addressing visual memory can be used so that students can see the structure of the topic and the relationship between the key concepts.
3. In exams, while the difficulty level of questions is determined, the relation between the problem solving steps and WMC ought to be considered, and the solution steps of the problems should be within WMC of the students.
4. Because of the fact that chunking certainly reduces memory load, teachers should train students to see the things as larger and fewer chunks, in order to avoid the overloading of the working memory with vast amount of information.
5. Careless use of language can also cause overloading WMC. Using unfamiliar vocabulary or familiar vocabulary in an alien context and employing negatives in exam questions or during teaching can effect learning (Cassels and Johnstone, 1984). Therefore teachers and text book writers should be careful about using the language and selecting the terminology.

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