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Can a Multimedia Tool Help Students' Learning Performance in Complex Biology Subjects?

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The aim of the present study was to determine the effects of multimedia-based biology teaching (Mbio) and teacher-centered biology (TCbio) instruction approaches on learners' biology achievements, as well as their views towards learning approaches. During the research process, an experimental design with two groups, TCbio ($n = 22$) and Mbio ($n = 26$), were used. The results of the study proved that the Mbio approach was more effective than the TCbio approach with regard to supporting meaningful learning, academic achievement, enjoyment and motivation. Moreover, the TCbio approach is ineffective in terms of time management, engaging attention, and the need for repetition of subjects. Additionally, the results were discussed in terms of teaching, learning, multimedia design as well as biology teaching/learning.

Keywords: keys for biology teaching; multimedia design; nervous system; science teaching; secondary school students

Introduction

Science Teaching and Multimedia

Classrooms are still based on teachers' oral explanations, and they also present inadequate learning environments to learners for the learning process mainly of science in several developing countries, such as Taiwan, South Africa and Turkey (Bester & Brand, 2013; Hong, Hwang, Liu, Ho & Chen, 2014).

Generally, science subjects include more abstract phenomena and concepts; therefore students have difficulties, such as the lack of ability to create concrete constructs in their own cognition system, misunderstanding theoretical components, as well as difficulties in using high order thinking skills (Yumusak, Sungur & Cakiroglu, 2007) in the learning process (Barak, Ashkar & Dori, 2011; Elliot, Wilson & Boyle, 2014; Starbek, Starçiç Erjavec & Peklaj, 2010). In this context, with the aim of providing more effective science teaching and learning environments, visual materials should be used. However, a case study conducted by Lemberger, Hewson and Park (1999) focuses on prospective secondary biology teachers' relationships between their classroom practice on the one hand, and their conceptions of biology and of teaching science on the other. The findings show that memorisation of science subjects or concepts via pictures is not enough to understand the core meaning of a subject. Similarly, Tekkaya, Özkan and Sungur (2001) stressed that while learners need to create a meaningful knowledge scheme in their cognitive structure, they tend to learn by rote biological concepts or subjects. Consequently, science subjects or courses, such as physics (Zheng, Yang, Garcia & McCadden, 2008), chemistry (Özmen, Demircioğlu & Coll, 2009), Mathematics (Maree, Aldous, Hattingh, Swanepoel & Van der Linde, 2006) and biology (Özay Köse & Çam Tosun, 2011; Öztap, H, Özay & Öztap, F, 2003), are generally considered so difficult by students.

In order to overcome these difficulties for science teaching and learning, various researchers have focused on computer assisted instruction (CAI) via multimedia teaching tools having different design structures to provide more effective teaching and learning in elementary, secondary and higher education (Barak et al., 2011; Elliot et al., 2014; Han, Eom & Shin, 2013). According to Mayer (2003), students can learn better in environments in which well-designed multimedia learning tools are used. This claim is based upon the fact that students learn better with pictures and words (visual and verbal) than with words alone. Furthermore, Schnotz (2008) emphasised that there are different effects of multimedia on the learner cognitive system, such as the enabling effect, and the facilitating effect. The enabling effect reduces learning time and cognitive load, while the facilitating effect allows learners to manipulate pictures which are different from static pictures; however, this situation may sometimes cause ineffective learning (Schnotz & Rasch, 2005).

In addition to these advantages, another positive effect of multimedia on teaching and learning is related to learners' motivation. Elliot et al. (2014) state that multimedia tools increase learners' motivation in the learning process of science. Furthermore, the results of a recent review study conducted by Moos and Marroquin (2010) showed that different types of CAI, such as multimedia, hypermedia and hypertext, affect theoretically-grounded constructs of motivation, such as mastery goal, performance goal, individual interest, situational interest, intrinsic motivation, extrinsic motivation and self-efficacy.

On the other hand, according to the redundancy principle, presenting learners duplicate narration and text simultaneously is improper (Pastore, 2012). Accordingly, multimedia teaching/learning material may complicate or hinder the learning/teaching process, if a multimedia material ignores the principle. Besides, the segmenting principle shows the importance of learner-control on multimedia material (Mayer & Moreno, 2003).

Otherwise, a continuous unit that does not allow teacher/learner control over the material, could cause an increase in the cognitive load and affect the learning process negatively.

Teaching Biology, the Nervous System and Problems

Biology is an important part of science teaching and it also plays a central part in areas such as medicine, agriculture and psychology. The human nervous system is made up of elements from the nervous system of certain animals (*hydrozoa* and *ammelida*), elements exclusive to the human nervous system itself (central nervous system, structure of brain, and structure of peripheral system), and the structure of its constituent cell, the neuron cell. Like many topics in the biology course, these subjects are rather abstract for learners. Therefore, students may have learning difficulties and misconceptions (De Villiers, 2011; Maree et al., 2006; Tekkaya, Çapa & Yilmaz, 2000). Moreover, Tekkaya et al. (2001) states that the nervous system is very difficult for students to learn. Similarly, Bahar, Johnstone and Hansell (1999) emphasise that when it comes to the central nervous system, sense organs and co-ordination topics present the greatest amount of learning difficulties for students. A recent case study conducted by Brown, Friedrichsen and Abell (2013) state that though teachers are aware of the students' learning difficulties in the biology course, they give priority to the transmission process of information to the learners. In this context, new teaching approaches like CAI are essential for effective science teaching. Unfortunately, according to Chang (2002:81) research aiming to determine "how various teaching formats of CAI can influence students' science learning outcomes in secondary education" is sparse.

Research Questions

The main purpose of the present study was to determine the effects of Mbio and TCbio instructtion approaches on learners' Biology achievements, as well as their views towards learning approaches. Based on this purpose, the following research questions were investigated:

- Is there a significant difference between the students' Biology achievement (BA) scores in the Mbio and TCbio groups?
- What are the students' views regarding the Mbio and TCbio approaches as they relate to positive and negative aspects, understanding, learning outcomes and affective characteristics?

Method

The study was conducted on a total of 48 Grade 12 students studying at two high schools located in Ankara and Istanbul, Turkey. These students were randomly assigned as experimental and control groups. The present research used an experimental design, including pre- and post-test groups. In the experimental group (n = 26) the teacher used an Mbio tool for instruction. In the control group (n = 22), TCbio instruction was used. At the end of the research process, interviews were conducted with 20 randomly selected students; half were from the Mbio Group, and the rest were from the TCbio group.

The Learning Content

The learning content basically includes the neuron system. All the subjects are given in Figure 1.

Structure of Mbio Tool

The Mbio tool was designed by researchers. Furthermore, during the development process of the tool, multimedia material development principles such as modality (Mayer, 2001; Sweller, 2005), multiple representation (Mayer & Anderson, 1991), coherence, contiguity and redundancy (Mayer & Moreno, 2002) were taken into consideration.

Basically, the Mbio tool includes several sections and sub-sections. Each section starts with a multimedia video (see Figure 2), with the aim of drawing the attention of the students. According to the course subject, embedded simulations were used to explain the core meaning of subjects/concepts (see Figure 3). Additionally, audio explanations and embedded audio-visual animations, which were controlled by the teacher via control buttons and sub-sections, were used.

Procedures Used in the Mbio and TCbio Groups

In the Mbio and TCbio groups, different instructtional procedures were used during the research process (five weeks). In the first week, the material was used twice in two sessions. Each session lasted for 40 minutes, during which, the material was used totally (40' + 40') as two course hours. In the second week, similar procedure with the first week (two sessions as 40' + 40') was applied by using the material. In the third, the fourth and the fifth week, one session (80') was applied separately. The detailed structure of procedures used in both groups is explained separately in the following sections.

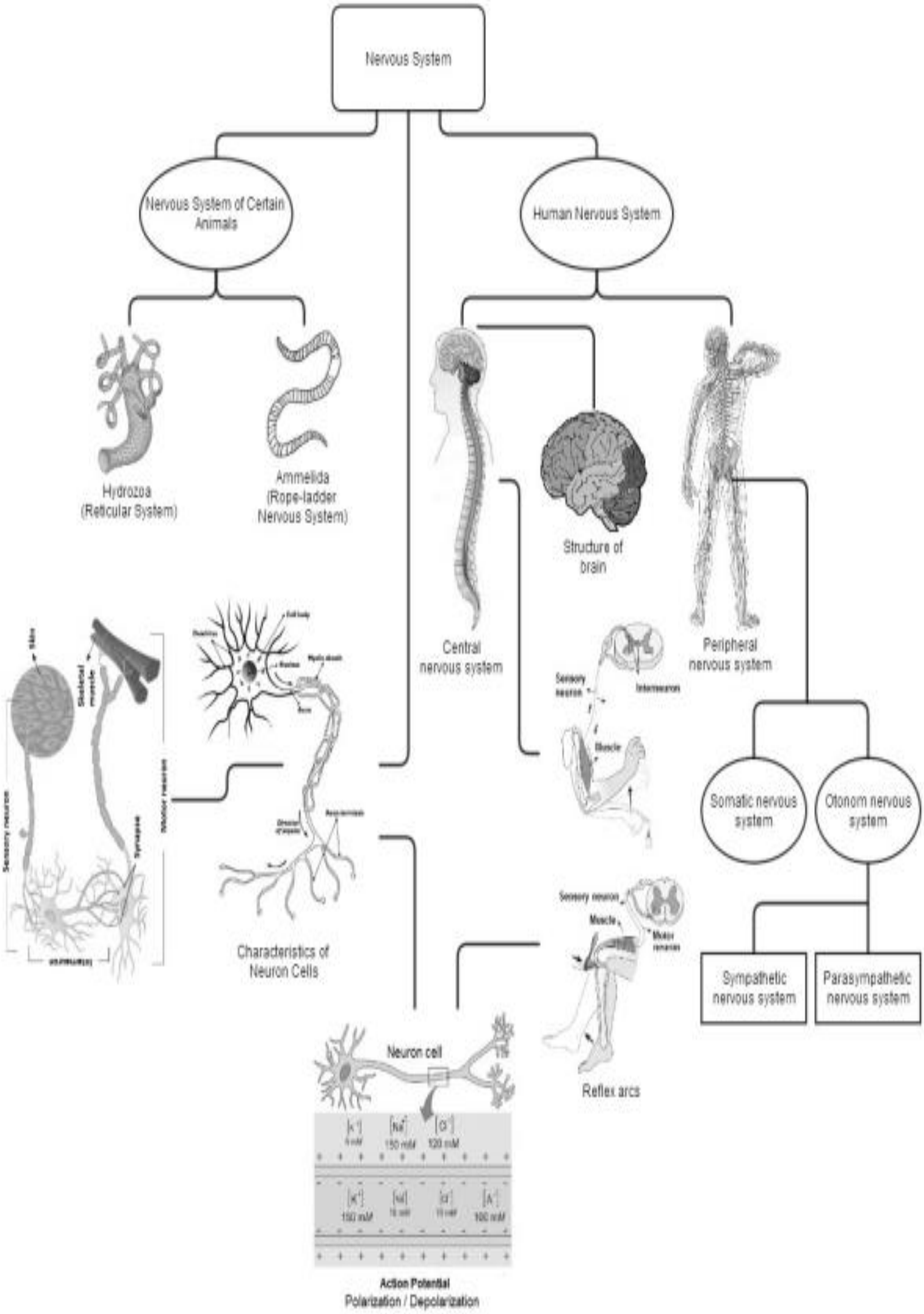

Figure 1 Content of the study

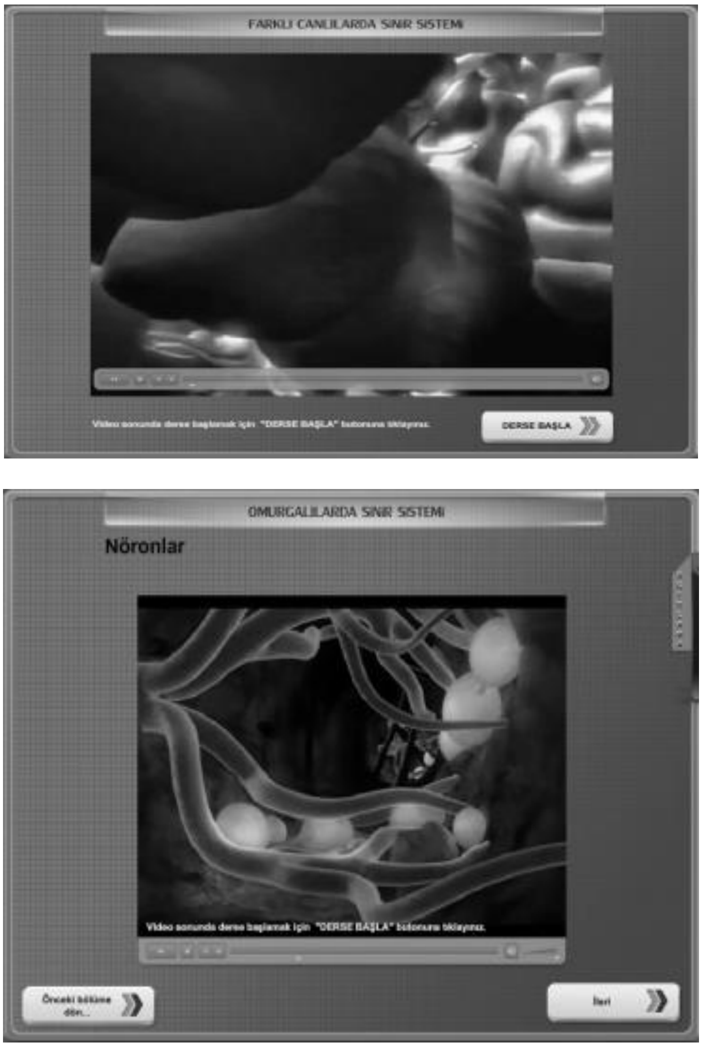

Figure 2 Screenshots of the video used as an Mbio tool

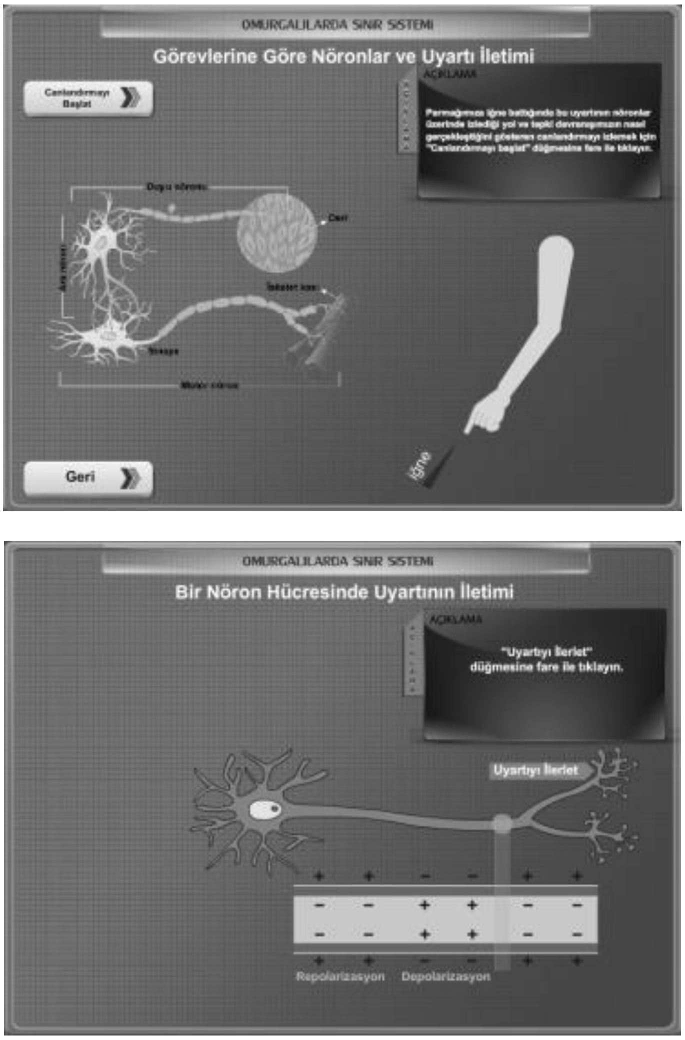

Figure 3 Simulation's screenshots used as an Mbio tool

Procedure of the Mbio group

In the group, the teacher used computer-assisted instruction via an Mbio tool. First, the course started by using the Mbio tool. Second, when the students did not understand the subject/concept, the teacher could give additional directions to them and they took notes. Third, the teacher asked questions to students about biology subjects and they gave explanations to the teacher. Fourth, animations related to the questions were presented via the Mbio tool. In this process, students questioned their previous explanations, and the information that was presented in the animations. Finally, they regulated their explanations by taking into account the information presented by the animations in the Mbio tool.

Procedure of the TCbio group

In this group, a teacher-centered biology teaching approach was used. Each week, the teacher first gave an oral presentation to students with the aim of drawing their attention and explaining the structure of the biology subject/concepts, without using any multimedia. Furthermore, at the end of the first step, the teacher instructed the students to take notes related to the biology subjects/concepts, which were presented in the first step. Second, the teacher asked questions to students and they answered the questions with oral explanations. Third, according to the explanations given by the students, the teacher gave confirmatory/explanatory feedback, such as "yes-true-correct, you are right" or "…your answer is not fully true because…" Finally, the teacher finished the course.

Data Collection Tools

In the current study, two different data collection tools were used. Specifications and basic structures of these tools are explained in the following sub-sections in detail.

Biology achievement (BA) test

During the development process of the BA test, a pilot study was conducted. In the first version (v1) of the BA test, there were 49 multiple-choice items. The v1 form of the BA was applied to 129 students who graduated from high school six months before the study. After that, an item analysis was conducted on data obtained from these students. In the process of item analysis, discriminative values of each item were calculated. Additionally, an independent sample *t*-test was conducted between the upper 27% and lower 27 percent. Finally, items that had a discriminative index lower than .25, and those items deemed unsuitable according to independent sample *t*-test results, were removed from the v1 form (in total 14 items were removed). The second version (v2) form of the BA (final form) includes 35 items and its KR-20 reliability coefficient was determined as .82. Finally, the BA test was used as pre- and post-test in both the Mbio and TCbio groups.

Structure of student interview (SI) form

The aim of the student interviews (SI) was to determine key factors that affect students' learning in terms of the specifications of the approaches used in the groups and students' learning performance in the learning environments. In this regard, the following research questions were answered:

- What are the students' views towards the Mbio/TCbio learning environments?
- What are the views of students towards their own learning performance in the Mbio/TCbio environments?

Furthermore, students' interviews were recorded and transcripts were then transformed by the researchers; each transcript was titled as view of student-1 in Mbio/TCbio group etc. (View-St.1-Mbio/View-St.1-TCbio). Then two copies of each transcript were made and the coding process for the transcripts was performed by one of the researchers and an independent Doctor of Philosophy (PhD) candidate for each transcript separately. The first coder identified 36 codes in total on the transcripts and the second coder identified 31 codes on the transcript. Moreover, while the coders agreed on 28 of them, they did not agree on 11 of them. Finally, according to Miles and Huberman's (1994) inter-coder reliability test result, reliability of SI was determined as 0.72 (see Equation 1).

$$\left[\ Intercoder\ reliability\ of\ SI = \frac{28}{28+11} = 0.72\ \right]$$

Equation 1 Reliability of SI

Findings

In this section, the findings of the study are shown in separate sub-sections. In the first sub-section findings are related to Question 1 of the study, and in the second sub-section findings are related to Question 2 of the study are presented.

Findings related to the First Research Question

In order to determine the results of the first research question, firstly, a *t*-test analysis was conducted between the pre-BA scores of the students in the Mbio and TCbio groups. The results of the *t*-test are shown in Table 1.

Table 1 *T*-test results of pre-BA scores of the students in Mbio and TCbio groups

Groups	*N*	$\bar{x}$	*SD*	*df*	*t*	*p*
Mbio	26	10.50	4.23	46	1.294	0.202_a
TCbio	22	9.09	3.11			

Note: a = *p* > 0.05.

According to Table 1, it is determined that there is no significant difference between the students in the Mbio and TCbio groups in terms of their pre-BA test scores [t (46) = 1.294, $p > 0.05$]. Additionally, an analysis of covariance (ANCOVA) was performed between the post-BA scores of the students. Moreover, before the ANCOVA test, its assumptions such as homogeneous variance and normality were tested. The results of the ANCOVA test are given in Table 2.

According to Table 2, it is determined that there is a significant difference between the post-BA scores of the students in the Mbio and TCbio groups [F (1-45) = 17.071; $p < 0.001$]. Besides, a Least Significant Difference (LSD) post-hoc test analysis was conducted in order to determine how the difference favours either group. The results of the test are shown in Table 3. Additionally, changes in pre- and post-BA scores of the students in the Mbio and TCbio groups, given in Figure 4.

According to Table 3, it is determined that average post-BA scores of the students in the Mbio group (21.01) are significantly higher than those of the students (15.07) in the TCbio group ($p < 0.001$).

Findings Related to the Second Research Question

Students' interviews in the Mbio group

So as to determine the views of students in the Mbio group, an inductive content analysis approach was used. The results of the analysis are shown in Table 4.

According to Table 4, it is determined that there are 21 codes, which were obtained from the students' interviews. These codes are assigned under three different themes, which are titled advantages, learning, and disadvantages, respectively. Additionally, in the theme 'advantages', there are three different sub-themes, namely 'approach', 'cognitive' and 'affective'. Furthermore, the 'approach' sub-theme is the most prominent, including nearly half the codes (n = 10).

Table 2 Post-BA ANCOVA results between the students in Mbio and TCbio groups

Source	Sum of squares	*df*	Mean square	*f*	*p*
pre-BA	15.870	1	15.870	0.668	0.418
Group	405.800	1	405.800	17.071	0.000[a]
Error	1069.738	45	23772		
Corrected total	1537.917	47			

Note: a = $p < 0.001$.

Table 3 LSD post-hoc test results for pairwise comparisons

Groups	*N*	$\bar{x}$ (means)[a]	Std. Error (*SE*)	*p*
Mbio	26	21.01	1.43	0.000[b]
TCbio	22	15.07		

Note: a = Covariates appearing in the model are evaluated at the pre-BT scores (9.85); *b* = $p < 0.001$.

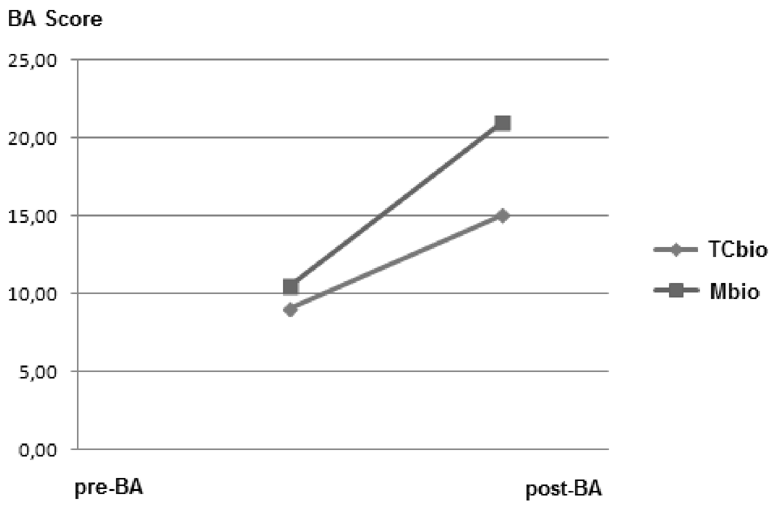

Figure 4 Line chart of students' pre and post-BA scores

Table 4 Content analysis of the students' interviews in Mbio group (n = 10)

Theme(s)	Sub-theme(s)	Code(s)	*f*
Advantages	Approach	Providing easy learning environment	10
		Concretion	8
		Visuality	7
		Providing opportunity for the revision of subjects	5
		Audio-verbal effect	4
		Effective teaching	4
		Suitability for the learner	2
		Finding out the details of the course	2
		Getting attention	2
		Avoiding unnecessary details	1
	Cognitive	Providing visual connotation to remember	5
		Flexibility	1
	Affective	Motivating to course	6
		Providing positive effect on the opinions of the students about the course	5
Learning		Effective learning	8
		Permanent learning	4
		Acquiring the core meaning of the subject	3
		Learning how to learn	1
Disadvantages		Partial learning	2
		The ineffectiveness of unable to note-taking	2
		Boredom	1

Students' interviews in the TCbio group

An inductive content analysis approach was used in order to determine the views of students in the TCbio group. The results of the analysis are shown in Table 5.

As shown in Table 5, it is determined that there are 18 codes, which were obtained from the students' interviews. These codes are assigned under two different themes, entitled 'approach' and ‘learning’, respectively. In addition, in the ‘learning’ theme, there are two different sub-themes entitled ‘cognition’ and ‘affective’. Furthermore, the ‘approach’ theme and ‘cognition’ sub-theme are prominent ones, as they include nearly all of the codes (n = 15/18). Only three codes are ranked as being in the “affective” sub-theme.

Table 5 Content analysis of the students’ interviews in TCbio group (n = 10)

Theme(s)	Sub-theme(s)	Code(s)	*f*
Approach		Need for repetition of subjects	8
		Boredom	8
		Ineffective time management	3
		Disadvantage of continuous note-taking	2
		Inactivation	2
		Note-taking enhances learning	2
		Concretion	1
Learning	Cognition	Inefficient learning	6
		Negative effect of unknown words on learning	4
		Transient learning	4
		Effective learning	3
		Abstractness of subjects	3
		Difficulty in memorising	2
		Superficial learning	2
		Rote learning	2
	Affective	Unable to concentrate on the course	7
		Less interest towards course	5
		Having prejudice toward course	3

Discussion and Conclusion

In this section, all the quantitative and qualitative results are discussed together to draw a concrete meaningful picture in terms of explaining students’ achievement, characteristics and the effect of learning environments (Mbio-TCbio) on students. Additionally, quotations from students’ interviews are presented in the text, with a view to increasing the structural validation of the study and reliability.

The results of the *t*-test between the pre-BA scores of the students in the Mbio and TCbio groups show that there is no difference in both groups in terms of their readiness/prior knowledge levels about the biology course. This finding is vital to revealing the effect of the Mbio and TCbio approaches on students’ achievement/learning clearly; where the results of recent research show that students’ prior knowledge levels affect students’ new learning process (Amadieu, Tricot & Mariné, 2009; Moos & Azevedo, 2008; Shapiro & Niederhauser, 2004; Tzu-Chien, Yi-Chun & Paas, 2014). In this regard, the results of the ANCOVA analysis on the post-BA scores of the students show that the students in the Mbio group have much higher achievement scores than do those in the TCbio group ($\dot{X}$Mbio = 21.01; $\dot{X}$TCbio = 15.07), which shows evidently that the Mbio approach is effective on students’ learning. The results of previous research support this finding (Efendioğlu, 2012; Jan, De Kruif & Valcke, 2012; Starbek et al., 2010; Su, 2008); however, the question of how Mbio/TCbio approaches affect the learning environment, students’ learning performance and their cognitive and affective structures, is vital. In this context, the results of the students’ interviews open a new path for student learning, via a multimedia tool and teacher-centred teaching in terms of science teaching and learning process.

According to the results of the students’ interviews in the Mbio group, three different themes were classified, namely: ‘advantages’, ‘disadvantages and ‘learning’. The ‘advantages’ theme mainly shows the positive effects of the Mbio tool and it also has three different sub-themes, namely: ‘approach’, ‘cognitive’ and ‘affective’. Furthermore, most of the codes are in the ‘approach’ sub-theme and all the students (n = 10/10) state that the Mbio approach provides an easy learning environment for learners, as noted by Student 1 (Mbio) who stated: “*...I think that I comprehended the course subjects more easily*…”. This statement indicates facilitating, which is one of the most recognised effects of multimedia (Schnotz, 2008). Additionally, most of the students made remarks related to “concretion” (n = 8/10) and “visuality” (n = 7/10) codes. Moreover, the students who expressed views regarding these codes focused on the structure of course subjects crystallising on their mind, such as Student 2 (Mbio), who noted: “*…in the previous course I was only taking notes and listening to my teacher’s explanations; therefore, all rules and relations between the subjects was flying away* [sic] *but these subjects are still in my mind…*”, which is indicative of concretion. As consistent with Dunsworth and Atkinson (2007), we argue that this concretion is an outcome of visuality. Additionally, half of the students (n = 5/10) stated that the Mbio tool provided review of the course subjects. On the other hand, nearly half of the students (n = 4/10) noted the “audio-verbal effect” and “effective teaching” codes, both of which may be explained as the modality principle (Mayer, 2001; Sweller, 2005), which claims that animations with supported audio-verbal explanations are more effective than animations with supported written texts. Two of the students stated that the Mbio tool offered a suitable structure for students. This code is interesting, in that, according to Piaget's Cognitive Development Theory, these students are in the formal operational stage; however, they need to work on concrete subjects. This discrepancy may derive from the fact that this is the students' very first encounter with these subjects, because a complex subject that is encountered for the first time may be assigned as abstract. Additionally, finding out the details of the course (n = 2/10) and avoiding unnecessary details (n = 1/10), codes may be evaluated as proper/fit structure of the Mbio tool. Moreover, students (n = 2/10) stated that the Mbio tool was effective for 'paying attention'. Student 5 (Mbio) noted: "*…when my teacher presented videos at the beginning of the course, I was not able to resist watching them, so I was necessarily established on the course…*" [sic].

On the other hand, regarding the 'cognitive' sub-theme, we found two codes: 'providing memorable visual meaning' (n = 5/10) and 'flexibility' (n = 1/10). The providing memorable visual meaning (knowledge) code supports students' cognitive schema in terms of recall knowledge, where the Mbio tool provides students with visual (both static and dynamic images), textual explanations and audio-verbal stimulus. Although these are different types of stimulus, they focus on common logical purpose in a specific subject, so they may create a powerful knowledge structure in students' minds as mentioned in Buzan and Buzan's (1993) mind map. According to Buzan and Buzan (1993), to harness the full range of cortical skills, word, image, number, logic, rhythm, colour and spatial awareness should be combined, where learners may reveal their full cognitive capacity. Additionally, the association process in students' mind is a flexible one, as each student may extract different meaning from a stimulus.

On the other hand, one of the most important sub-themes is 'affective'. In the sub-theme, there are two codes, 'motivating towards the course' (n = 6/10) and 'providing positive effect' on the students' opinions about the course (n = 5/10). Both codes show that the Mbio tool is powerful in terms of motivating the students towards the course, which has an important characteristic for effective learning (Meyer, McClure, Walkey, Weir & McKenzie, 2009; Plass, Heidig, Hayward, Homer & Um, 2014).

In the "learning" theme, there are four codes. One of the most important ones is "effective learning" (n = 8/10), which clearly shows the students' achievement in the Mbio group. Furthermore, "permanent learning" (n = 4/10), 'acquiring the core meaning of the subject' (n = 3/10), and 'learning how to learn' (n = 1/10) codes support this idea. In fact, this theme may be evaluated as a natural result of the advantages theme, where cumulative advantages (approach, cognitive, and affective) of the Mbio tool form a holistic structure of learning. Additionally, Barak et al. (2011) have stated that students studied by means of science animations, and thus, their motivational and cognitive characteristics are affected positively with regard to effective learning. Nevertheless, the disadvantages theme presents some negative aspects of the Mbio tool. In this theme, the codes 'partial learning' (n = 2/10), 'ineffectiveness of not being able to take notes' (n = 2/10) and 'boredom' (n = 1/10) pertain, which were stated by relatively few of the students. These codes may be related to students' learning styles since some students stated their views, such as Student 4 (Mbio), who noted: "*...writing was more effective than this approach. I used to learn by writing, it was such a different experience for me…*"; and Student 8 (Mbio), who noted: "*...only watching and listening is ineffective and I was bored. There is no information to review at home… .*"

As for the results of the analysis of students' views in the TCbio group, it was determined that there are two themes, namely 'approach' and 'learning'. In the 'approach' theme, there are seven different codes. While most of them are related to negative views, only two of them are positive. Furthermore, the most prominent codes are the need for 'repetition of subjects' (n = 8/10) and 'boredom' (n = 8/10), where students state their views as follows. Student 2 (TCbio) noted: "*…only using the knowledge that I learned during the course, [it] is not possible to succeed in the course, I must review the subjects at home…*"; Student 3: "*…I would not say I learned everything, I learned something; however, due to continuous note-taking, I could not understand what these sentences mean…*"; Student 7 (TCbio) noted: "*…I was constantly taking notes and I understand nothing. Actually, I do not know how a signal is transmitted to another neuron and I was bored…*" [sic]. In this regard, another code, entitled 'ineffective time management' (n = 3/10) has one of the most expected results. Moreover, two students clearly expressed the disadvantage of continuous note-taking. Additionally, the code 'inactivation' (n = 2/10) may be interpreted as a result of boredom and continuous note-taking. Besides this, students' active participation in the learning process is not only limited to learning by doing but it is also related to students' cognitive participation. Hence, the inactivation code may be regarded as no cognitive participation. On the other hand, one of the interesting codes is that of 'note-taking enhances learning' (n = 2/10), where students expressed their opinions as follows. Student 1

(TCbio) noted: "…*when I am taking notes I can review my notes at home so I can learn easily*…"; and Student 4 (TCbio) commented: "…*I learn better when I am simultaneously taking notes and listening to my teachers*…". While the students in the TCbio group have lower achievement scores than do students in the Mbio group, their views may reflect their learning styles.

In the learning theme, there are two sub-themes, 'cognition' and 'affective'. It is thought that the codes in these sub-themes might explain the reasons why the students in the TCbio group have lower achievement scores than the students in the Mbio group. In the cognition sub-theme, 'inefficient learning' (n = 6/10), 'transient learning' (n = 4/10), 'superficial learning' (n = 2/10), and 'rote learning' (n = 2/10) codes show that the students cannot constitute cognitive structure in terms of creation of core meaning of the subjects. Moreover, 'abstractness of the subjects' (n = 3/10) and 'difficulty in memorising' (n = 2/10) codes support this. Additionally, students' views pertain as follows. Student 3 (TCbio) noted: "*...I do not know how can to say this…I can understand/take in mind a little bit at a time*…" [sic]; Student 5 (TCbio) noted: "…*I comprehended some basic concepts; however, generally, I cannot understand the subjects*…"; Student 8 (TCbio) noted: "*...I can remember something but due to continuously writing I could not understand the subjects… If there were some pictures in the course, I would understand and remember...*" are drawing a concrete picture that abstract subjects, supported by concrete models or pictures, provide effective teaching/learning. Another interesting code is the 'negative effect of unknown word on learning' (n = 4/10). Despite the fact that both students in the Mbio and TCbio groups worked on the same subjects (content), the students in the Mbio group have no opinions about the unknown words, compared to the students in the TCbio group. This finding is similar to the finding of a study conducted by Ayas, Çlepni and Akdeniz (1993). Ayas et al. (1993) stated that lots of concepts in the biology course are of English origin, and for this reason, students experience learning difficulties, not knowing the English origin of the words. Even if we share these opinions with them, this explanation is not enough, since students in the Mbio group cannot be seen to state similar views to those in the TCbio group. It is thought that the students in the TCbio group could not construct a holistic structure for the subjects, so they were unable to acquire the core meaning of concepts or terms, and consequently, experienced learning difficulties.

On the other hand, in the 'affective' sub-theme there are three different codes such as 'unable to concentrate on the course' (n = 7/10), 'less interest in the course' (n = 5/7), and 'having prejudgment towards the course' (n = 3/10). Accordingly, it is thought that the TCbio approach has insufficient structure in order to provide the requisite motivational factors for students. Moreover, Chen and Sun (2012) remarked that there are negative correlations between students' emotional characteristics and their learning performance. Finally, it is known that student learning is impossible in an environment that supports neither the cognitive nor affective structure of students (Alonso-Tapia & Pardo, 2006). Additionally, teaching and learning approaches that enable students to learn effectively should be taken into account.

Implications

Given the strength of the results of the present study, there are several significant proposals for both instructors and multimedia learning environment designers, especially for newly industrialized countries, such as Brazil, China, India, Malaysia, Mexico, the Philippines, South Africa, Thailand and Turkey. During the decision-making period pertaining to the teaching and learning approach to be used in the teaching-learning environment, the concretising of subjects, facilitating, and visualisation ought to be taken into consideration by instructors. Moreover, the approach should support learners' motivation and enjoyment. Rather than students continuously note-taking, instructors should prefer to have students take short notes during the teaching process. The meanings of the concepts should be presented as an aggregate.

Thus, students can acquire the meaning of concepts from their own knowledge structure, and in this way, students can learn meaningfully, rather than rote learn. As teaching of science subjects includes abstract things and concepts, the teaching /learning process can be better supported via multimedia enhanced materials.

In the process of designing a multimedia teaching and learning tool, designers ought to prefer dynamic visualisation techniques (simulation /animation) rather than static visualization. Moreover, apart from known multimedia design principles (modality, multiple representation, coherence etc.); and for teaching/learning tools, visually stimulating videos/animations should be used as both advance organisers and emotional-motivational supporters. On the other hand, the study focused on the achievement and views of the students. However, it is a generally known fact that affective characteristics of the student and learning styles may affect students' achievement and views. Therefore, further studies should take these characteristics into consideration. Additionally, it is thought that the results of further studies, which may benefit from a larger sample size, might reveal new insights in terms of understanding more clearly the validity of the results of a study of this kind.

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