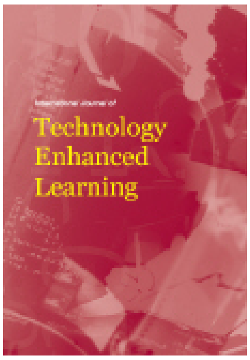

International Journal of Technology Enhanced Learning

ISSN online: 1753-5263 - ISSN print: 1753-5255
https://www.inderscience.com/ijtel

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DOI: 10.1504/IJTEL.2023.10052482

Article History:

Received:	31 May 2021
Last revised:	19 October 2021
Accepted:	06 November 2021
Published online:	22 December 2022

Brain-compatible courseware impact on learning computer programming

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Abstract: The purpose of this study is to investigate the effect of brain-compatible courseware on students' learning achievement and retention in computer programming course. In this quasi-experimental study, 60 eleventh grade female students in computer vocational schools were randomly assigned to two experimental groups and one control group of 20 each. The control group was taught in the conventional method. The first experimental group used the researcher-made brain-compatible courseware and the second experimental group used the non-brain-compatible courseware. A researcher-made programming test was conducted as the pre-test, post-test and retention test. The results of the ANCOVA test indicate that using the brain-compatible courseware significantly improves the students' learning achievement and retention compared to the second experimental and control group students ($p<0.05$). It is inferred that the use of brain-compatible courseware is more effective than the use of non-brain-compatible courseware and the conventional method.

Keywords: brain-based learning; courseware; learning; retention; computer programming; visual basic.

Reference to this paper should be made as follows: Badiee, E., Nili, M.R. and Abedini, Y. (2023) 'Brain-compatible courseware impact on learning computer programming', *Int. J. Technology Enhanced Learning*, Vol. 15, No. 1, pp.1–13.

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1 Introduction

With the increasing use of modern technology, human beings have stepped into the e-learning and computer-based learning domain, where Information and Communication Technology (ICT) has transformed the learning conditions (Sompong and Kheerajitt, 2012). E-learning is a new and fast approach to acquiring knowledge, experience and skills. Nowadays, schools are trying to take advantage of this method to enhance student learning (Lin et al., 2014). One of the e-learning products is courseware. In general, any course instruction provided through software or the Internet is called courseware (Ghirardini, 2011). Although technology provides the teaching instrument, it does not guarantee its success. The e-learning content should be designed compatible with the learning principles in a manner that actively involves the learners and enhances their learning (Anderson, 2008). One of the main problems with using new learning opportunities is the unavailability of high-quality courseware (Grutzner et al., 2002; Wang, 2017). Owing the not observing learning principles and disregarding the educational psychology principles, most of the available educational software is not appealing to the learners and does not have an appropriate effect on learning. To be effective, courseware developers must take advantage of multimedia learning with respect to the principles of psychology and learning theories (Lu, 2018).

Being aware of how the brain functions while learning has important implications for education (Sprenger, 2010). By applying this knowledge in curriculum planning, learning can be enhanced in its highest possible sense in all individuals of different characteristics (Blakemore and Frith, 2005). Based on extensive researches in fields such as psychology, biology and neuroscience, Caine and Caine proposed a set of principles for brain learning (Caine and Caine, 1991; Jensen, 2008; Caine et al., 2015). Brain-based education constitutes learning through methods that the human brain is naturally designed for (Jensen, 2008). The main principles of brain-based learning consist of (Caine and Caine, 1991; Caine et al., 2015; Clemons, 2005; Lombardi, 2008; Ng, 2016; Sprenger, 2010):

1. Complex learning is enhanced by challenge and inhibited by threat
2. The brain/mind is social
3. The search for meaning is innate
4. Emotions are critical in patterning
5. The brain processes the parts and wholes simultaneously
6. In learning the entire physiology is engaged
7. The search for meaning occurs through the patterning
8. Learning is developmental
9. There exist at least two different types of memory: the spatial memory system and a set of systems for rote learning
10. Learning involves both focused attention and peripheral perception
11. Learning always involves both conscious and unconscious processes
12. Every brain is unique.

The experts and researchers in the field of mind, brain, and education propose many applications based on brain-based learning principles to improve learning and retention (Jensen, 2009; Wolfe, 2010). Most conducted research (83%) report the positive effects of applying brain-based learning principles on students' learning in different subject matters (Gozuyesil and Dikici, 2014).

In recent decades, many countries have incorporated computer science as part of formal school education, especially in secondary education (Dagiene and Hellas, 2017). Computer programming is one of the most challenging courses to learn in this field (Robins et al., 2003; Mather, 2015; El-Zakhem, 2016). These lessons require the preparation of effective learning materials and the use of new learning strategies (Dagiene and Hellas, 2017). In this domain, the brain and memory functions are essential (Davidson et al., 2003). This course is conceptually abstract, very tough to learn and seems boring (Liu et al., 2018). Applying strategies to improve the learning in this course, which is often not appealing to students, is one of the major concerns of teachers (Mather, 2015).

2 Review of literature

In recent decades, various studies have been conducted on the brain and its functionality during learning. However, there exist few studies on investigating the impact of brain-compatible e-learning material. Some studies investigating the effect of brain-compatible teaching on learning achievement across different courses indicate that the brain-based teaching strategies are more effective on students' learning achievement than that of conventional lecturing (Alanazi, 2020; Akasheh et al., 2018; Araghi and Moghaddam, 2013; Awolola, 2011; Duman, 2010; Griffee, 2007; Malik et al., 2012; Mekarina and Ningsih, 2017; Parnell, 2018; Saleh and Mazlan, 2019; Saleh and Subramaniam, 2018; Shabatat and Al-Tarawneh, 2016; Tufekci and Demirel, 2009; Uzezi and Jonah, 2017; Varghese and Pandya, 2016). Some other studies also show that these strategies have a positive effect on students' retention (Haghighi, 2013; Helaal, 2020; Salem, 2017; Tufekci and Demirel, 2009; Uzezi and Jonah, 2017).

Few studies investigated the effect of brain-compatible multimedia learning materials or brain-compatible courseware on learning and retention. The study conducted by Van Niekerk and Webb (2016) revealed that brain-compatible e-learning material has been able to increase the students' retention in programming logic more than the traditional teaching method.

2 Method

This study explored the following research questions:

1 What is the effect of using the brain-compatible courseware on vocational school students' learning achievement in computer programming course?

2 What is the effect of using the brain-compatible courseware on vocational school students' retention in computer programing course?

Based on the research questions, the following null hypothesis was formulated to guide the study:

H01: There is no significant difference ($p < 0 .05$) in the mean learning achievement scores of students taught computer programming using brain-compatible courseware, those taught with non-brain-compatible courseware and those taught with the conventional method.

H02: There is no significant difference ($p < 0.05$) in the mean retention-test scores of students taught computer programming using brain-compatible courseware, those taught with non-brain-compatible courseware and those taught with the conventional method.

3.1 Design

This quasi-experimental study was of the non-equivalent control group pre-test-post-test design. In the non-equivalent control group pre-test-post-test design, which is the most applied in educational research, the division of the participants into experimental and control groups is not random and all the groups are subject to pre-test and post-test. The non-equivalent group design can be applied to more than two groups (Gall et al., 2006). Because it was not possible to separate the students of each class for sampling and to assign them in groups in a random manner, the intact classes were used. As shown in Table 1, this study consists of three groups of participants (T1 = pre-test, T2 = post-test, T3 = retention test and X1, X2 = treatments):

Table 1 Study design

Group	*Pre-test*	*Treatment*	*Post-test*	*Retention test*
Experimental 1	T1	X1	T2	T3
Experimental 2	T1	X2	T2	T3
Control	T1	–	T2	T3

3.2 Statistical population and sampling

The statistical population in this study consists of all the female students of 11th grade in the computer field in vocational schools of XXX city in XXXX during the academic year 2019–2020. The research sample consists of six classes taken by applying the cluster sampling method. Two classes were randomly assigned to each group. In this way, 20 students were allocated in the first experimental group, 20 in the second experimental group and 20 in the control group.

3.3 Multimedia instructional materials

1) One courseware that is commonly available as multimedia material for teaching Visual Basic programming in XXXX schools.

This courseware includes a text-based menu and submenus. In each part of the courseware, textual and spoken explanations are provided, followed by a few samples. These examples are not related to real-life, and each is accompanied by images of program lines in the Visual Basic software environment. The variety of graphic and multimedia elements in this courseware is very limited. Interaction in this courseware is very low, and no feedback is provided. In this courseware, the brain-based learning principles were not observed.

2) One Courseware related to the Visual Basic 6 programming course was designed by the researcher and the expert's group (including professors in educational sciences, educational psychology, educational technology and computer science) founded on brain-based learning strategies.

The courseware was approved by five university experts in related fields and five computer programming instructors. A literature study was conducted to develop this courseware based on recommendations made by experts on the mind, brain and educational science, which led to a collection of brain-based learning strategies. The strategies emerged from brain-based learning principles applied in developing the courseware are:

- Presenting the lesson in a general and coherent structure, presenting a sequence of the subject titles, preview of the new lesson objectives and applications (Caine and Caine, 1991; Sousa, 2011; 2007; Jensen, 2005; Sprenger, 2010; Saleh, 2012) according to principles: 3, 5, 8.
- Applying organisational and graphic charts and conceptual maps (Jensen, 2005; Sousa, 2011; Sprenger, 2010; Connell (2005) according to principles: 5, 8.
- Storytelling and role-playing, providing examples of real-life, providing significant experiences related to real-life (Jensen, 2005, 2008; Sprenger, 2010; Sousa, 2011; Caine and Caine, 1991; Connell, 2005; Wolfe, 2010; Caine et al., 2015) according to principles: 1, 2, 3, 4.
- Providing relaxing music during the learning activities concerning time and type of activity (Caine and Caine, 1991; Sousa, 2011; Saleh, 2012; Connell, 2005; Jensen, 2005, 2008; Sprenger, 2010; Wolfe, 2010) according to principles: 1, 4, 10.
- Considering a reflection time between the learning periods and contemplating on emotions during learning (Caine et al., 2015; Jensen, 2005, 2008; Sousa, 2011; Connell, 2005; Sprenger, 2010) according to principles: 9, 11.
- Considering a relaxation time between the learning periods, and providing deep breathing and tension relief exercises and playing the sound of birds, animals and water flow at this time (Caine and Cain, 1991; Jensen, 2009, 2008; Connell, 2005; Smith, 2007) according to principles: 1, 6.
- Enriching the visual environment by applying different types of media, playing music, verbal or written emphasis on the key points, applying appropriate colours for stimulation or relaxation, adopting multi-dimensional teaching methods, applying all types of multiple intelligences concerning differences in individuals (Smith, 2007; Van Niekerk and Webb, 2016; Connell, 2005; Jensen, 2005, 2008; Caine and Caine, 1991; Sousa, 2011; Sprenger, 2010) according to principles: 8, 10, 12.

- Applying aesthetic, artistic and natural elements such as flowers and plants to make the learning environment pleasant (Jensen, 2005; 2008; 2009) according to principles: 1, 4, 10, 12.
- Considering entertainment and educational games to combine the motion activities in learning, verbal games, crossword puzzle solving, memory games to repeat and practice during learning (Jensen, 2005, 2008; Sprenger, 2010; Sousa, 2011; Wolfe, 2010; Smith, 2007) according to principles: 1, 4, 6, 9, 12.
- Reciting poetry or playing musical instruments, singing and presenting the key points in a harmonious manner (Connell, 2005; Jensen, 2005, 2008; Sprenger, 2010; Smith, 2007) according to principles: 1, 9, 10, 12.
- The briefing, summarising and reviewing the lesson after completing each section and before teaching the new subject by re-providing a general image of the lesson and applying the review strategies (Sprenger, 2010; Smith, 2007; Jensen, 2005, 2009; 2008; Sousa, 2011, 2017) according to principles: 5, 7, 8, 9.
- Presenting various challenging and relevant exercises and allocating the appropriate time, gradual learning during activities, testing together with educational feedback, applying self-assessment mechanisms as a review (Jensen, 2005, 2008; Sousa, 2011, 2017; Wolfe, 2010) according to principles: 1, 9, 11.
- Learning from the negative and positive during time, immediate and continuous feedbacks together with error correction, providing appropriate training as feedback, immediate rewarding and motivating, especially abstract rewards and exciting celebrations (Sprenger, 2010; Caine et al., 2015; Jensen, 2005, 2009, 2008; Sousa, 2017; Connell, 2005) according to principles: 4, 8, 9.
- Simulating and providing a condition similar to the reality, teacher role-playing in problem-solving and modelling the teacher's performance during the activities (Sousa, 2017; Sousa and Tomlinson, 2011; Spenger, 2014) according to principles: 2, 3, 7.
- Moving from concrete to abstract, connecting the new and prior knowledge, connecting the new matters with previous patterns in mind, attracting the students' attention towards lesson points in its overall context and applying yellow and red colours to stimulate the learners' attention (Sprenger, 2010; Connell, 2005, Jensen, 2005, 2008; Van Niekerk and Webb, 2016; Wolfe, 2010) according to principles: 3, 7, 8, 10.
- Allowing the students to choose the teaching process instead of a linear and obligatory process, concerning individuals' characteristics (Jensen, 2005; Caine and Caine, 1991) according to principles: 3, 12.

3.4 Data collection instrument

The instrument applied in this study for data collection was a researcher-made Visual Basic programming achievement test. This test consists of 25 multiple choice questions with one score each; that is, each student gains a score within the 0–25 range. The content validity of this test was subjected by three computer programming experts and computer educational group members of the XXX teachers' research centre. This test was implemented on 30 computer students as a pilot test, and the reliability of 0.746 was established through the Kuder-Richardson (K-R20) method.

3.5 Research process

Before the intervention, the three groups participate in the programming pre-test. The training period consists of 8×90 min sessions in the computer lab. In the control group, the teaching was conducted in the conventional method; that is; first, the teacher lectured the lesson to the students working in pairs, and then presented the course through a local-area network using Visual Basic programming software and the textbook content. In the first experimental group, in the first session, students learned how to use the brain-compatible courseware. After teaching each topic with the conventional method, they used the courseware, designed based on brain-based learning principles, in pairs with the teacher's directions. In the second experimental group, in addition to the conventional method, the non-brain compatible courseware available in the school was applied, where the students learned how to use it during the first session. After teaching each section in the conventional method, this group of students applied the courseware in pairs under the teacher's supervision. The same topics of the computer programming course were taught to these three groups during the experimental period, according to Table 2.

One week after completing the teaching, the same academic achievement test was applied as a post-test. This test is repeated after one month as a retention test to assess the students' retention levels.

Table 2 Arrangement and content of the lessons presented to the three groups

Session	*Educational content*
1, 2	General preliminaries on the decision making and control structures, their application and types together with the If control structure and its' syntax in both the multiline syntax and single-line syntax
3	The principles of combining expressions using logical operators and their application in conditional statements
4	Applying Select Case control structure in multiple conditions
5	General preliminaries on the repetition structures, definite and indefinite loop and their applications The structure and syntax of the For loops
6, 7	Applying indefinite repeat loop structures and syntaxes (While…Wend, Do While… Loop and Do… Loop While)
8	The immediate exit commands of different types of both the definite and indefinite loops (Exit Do and Exit For)

3.6 Data analysis

The data were analysed through the SPSS software. Descriptive statistics were applied to brief the data. The One-way Univariate Analysis of Covariance (ANCOVA) was used to analyse the data. The LSD analysis was used for the subsequent comparisons. In these analyses, the pre-test effect is adjusted. The most appropriate tool to analyse the data obtained from the control group pre-test-post-test design is the covariance analysis. The covariance analysis statistically adjusts the groups' previous differences effects in the post-test (Gall et al., 2006).

4 Findings

The descriptive statistics results reported in Table 3 indicate that the first experimental groups' programming pre-test scores (*M* = 5.80, SD = 3.04) are lower than that of the second experimental (*M* = 6.70, SD = 2.96) and control (*M* = 8.05, SD = 2.30) groups. In the post-test, the first experimental groups' mean scores (*M* = 13.45, SD = 3.89) are higher than that of the second experimental and control groups (*M* = 8.50, SD = 2.80 and *M* = 10.40, SD = 3.41, respectively). The pre-test and post-test score differences and difference between the retention and pre-test scores are higher in the first experimental group than that of the second experimental and control groups.

Table 3 Descriptive statistics of the experimental and control groups

Group	*Pre-test (T1)*		*Post-test (T2)*		*Retention test (T3)*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*
Experimental 1	5.80	3.04	13.45	3.89	11.80	4.37
Experimental 2	6.70	2.96	8.50	2.80	6.95	2.04
Control	8.05	2.30	10.40	3.41	10.25	4.55

First, it was examined whether there is a significant difference ($p<0.05$) in the mean learning achievement scores of students taught computer programming using brain-compatible courseware, those taught with non-brain-compatible courseware and those taught with the conventional method. For this reason, the one-way univariate analysis of covariance was conducted on post-test scores using pre-test scores as a covariate. Results presented in Table 4 indicate that there exists a significant difference between the programming scores of the participants in the post-test (F (60, 2) = 11.891, $p<0.05$). Therefore, the first null hypothesis was rejected.

Table 4 Results of single variable covariance analysis to compare achievement scores in the groups

Source	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*	*Eta squared*	*Observed power*
Pre-test	24.170	1	24.170	2.133	0.150	0.037	0.300
Group	269.492	2	134.746	11.891	0.000	0.298	0.993
Error	634.580	56	11.332				
Total	7885.000	60					

As reported in Table 5, the pairwise comparison of the adjusted post-test scores in these three groups indicates that the first experimental group students' mean scores where the brain-compatible courseware was used are significantly higher than that of the two other groups at $p<0.05$. By comparing the second experimental and control groups, it is indicated that although the mean scores of the control group without applying any courseware are higher than the second experimental group where the non-brain-compatible courseware was used, this difference is not significant at $p<0.05$.

Table 5 Pairwise comparison of the adjusted post-test scores in the three groups

Group(i)	*Group(j)*	*Mean difference (I–J)*	*Sig.*
Experimental 1	Experimental 2	5.160*	0.000
	Control	3.576*	0.002
Experimental 2	Control	–1.584	0.150

Furthermore, it was examined whether there is a significant difference ($p<0.05$) in the mean retention scores of students taught computer programming using brain-compatible courseware, those taught with non-brain-compatible courseware and those taught with the conventional method.

For this reason, the one-way univariate analysis of covariance was conducted on retention-test scores using pre-test scores as a covariate. As reported in Table 6, there exists a significant difference between the programming scores of the participants (F (60, 2) = 10.215, $p<0.05$). Therefore, the second null hypothesis was rejected.

Table 6 Results of single variable covariance analysis to compare retention-test scores in the three groups

Source	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*	*Eta squared*	*Observed power*
Pre-test	90.110	1	90.110	6.766	0.012	0.108	0.725
Group	272.079	2	136.040	10.215	0.000	0.267	0.982
Error	745.790	56	13.318				
Total	6688.000	60					

As shown in Table 7, it is revealed that the first experimental group students' retention scores, where the brain-compatible courseware was used, are significantly higher than that of the two other groups at $p<0.05$. Comparing the second experimental and control groups indicates that the control group students' retention scores without applying any courseware are significantly higher than the second experimental group where the non-brain-compatible courseware was used. Consequently, the brain-compatible courseware increases students' retention, while the non-brain-compatible courseware decreases the students' retention in a computer programming course.

Table 7 Pairwise comparison of the adjusted retention scores in the three groups

Group(I)	*Group(J)*	*Mean difference (I–J)*	*Sig.*
Experimental 1	Experimental 2	5.256	.000
	Control	2.566*	.040
Experimental 2	Control	–2.691*	.026

5 Discussion and conclusion

Computer programming is a high-level and complex skill in the computer sciences, the importance of which increases with the ever-growing changes in this technology. In this context, Visual Basic programming language is considered one of the most important and challenging subjects in the computer sciences branch in vocational schools. Very often, students demonstrate a low level of learning in this course. The experts in educational science seek to use the powerful features of a computer-based multimedia learning environment to improve student learning using appropriate courseware. The courseware should be designed according to learning principles. The most recent studies on neuroscience propose brain-based learning principles to maximise learning outcomes. There is little courseware for teaching Visual Basic programming language, while the available courseware is not efficient enough.

The study results indicate that the courseware designed founded on brain-based learning principles increases the students' computer programming learning. These findings correspond to results found in the literatures (Alanazi, 2020; Akasheh et al., 2018; Araghi and Moghaddam, 2013; Awolola, 2011; Duman, 2010; Griffee, 2007; Malik et al., 2012; Mekarina and Ningsih, 2017; Parnell, 2018; Saleh and Mazlan, 2019; Saleh and Subramaniam, 2018; Shabatat and Al-Tarawneh, 2016; Tufekci and Demirel, 2009; Uzezi and Jonah, 2017; Varghese and Pandya, 2016) where the computer and courseware were not applied. Hence, it can be noted that this study generalises the results of the previous studies on computer-based training. But these results do not correspond to the findings of Van Niekerk and Webb (2016), where the non-effectiveness of using the brain-compatible e-learning materials in the first post-test in the programming logic course is evident. As to the researcher's opinion here, the reason for this difference could be the vast application of the brain-based learning principles in the courseware applied in this study.

The results here indicate that the courseware designed founded on brain-based learning principles increases the students' retention in a computer programming course. These findings correspond to results found in the literature (Tufekci and Demirel, 2009; Haghighi, 2013; Uzezi and Jonah, 2017), where the positive effect of brain-compatible learning on the retention is revealed, while there, the programming course is not taught, and computer and courseware are not applied. Moreover, these results correspond to the findings of Van Niekerk and Webb (2016), where the positive effect of using brain-compatible e-learning material on students' retention in programming logic course is reported.

The results here indicate that the non-brain-compatible courseware does not make a significant difference in the students' learning achievement, and decreases the students' retention in a computer programming course. Anderson (2008) argues that although technology facilitates education, it cannot improve learning if it does not apply the learning principles. Consequently, the findings in this study correspond with the learning aspect of his argument, while the retention aspect is also assessed here.

According to the obtained results, by designing, developing, and applying brain-compatible courseware, the learners' learning and retention in computer programming can be improved. Although developing efficient courseware under the brain-based learning principles is not an easy task, investing in this method can pave the way to achieving educational goals in this context.

6 Limitations

The participants in this study consist of computer students with some computer experience and access to the computer. The limitation of this study consists of the possibility that not all communities may be equipped with these facilities and the fact that the participants in this study are female, where both prevent the generalisation of this study.

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