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OBM Neurobiology

Original Research

Enhancing Students' Brain Development through Technology Use and Digital Characteristics

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Academic Editors: María Jose Hernández Serrano and Paula Renés Arellano

Special Issue: Implications of Technologies on the Brain Development in Younger Students

OBM Neurobiology
2024, volume 8, issue 3
doi:10.21926/obm.neurobiol.2403242

Received: May 12, 2024
Accepted: August 14, 2024
Published: August 19, 2024

Abstract

In the present era of digitalization, technology plays a prominent role in relaxation and brain development (BD), specifically for university students. The present study explores the impact of technology use and digital characteristics (DC) in developing students' BD. We applied the quantitative methods; the study collected 328 samples from Egypt's different public sector universities through a questionnaire. Using path analysis through analysis of moment structures (AMOS), the results demonstrate a positive effect of rapid communication technology (RCT), web resource use (WRU), and digital characteristics (DC) on BD. On the other hand, multimedia creation (MC) was found to be the negative predictor of BD among the medical students of Egyptian public sector universities. The study outcomes would assist in developing strategies that enhance the technology for reducing students' tensions and study pressures. Moreover, the study would encourage the students to utilize digital technology to strengthen their BD and cognitive development. Finally, the study's findings would contribute to the literature on management, medical science, and information technology and add its share by adding empirical evidence from a developing

context, especially from medical institutions.

Keywords
Brain development; technology use; rapid communication technology; multimedia creation; digital characteristics; medical university

1. Introduction

The development of students' brain and cognitive abilities has emerged as a crucial concern for educational and learning institutions. This development leads to significant changes in mental functions, such as learning abilities and decision-making skills [1]. Notably, robust technology and conducive learning environments enhance students' brain development (BD) and cognitive skills [1, 2].

In the literature, there are several enablers, i.e., simulations, games, animations, digital books, learning strategies, multimedia creation (MC), digital media use, digital characteristics (DC), digital platforms, web resource use (WRU), learning and skills, use of online education, knowledge acquisition, rapid communication technology (RCT), motivation, digital technologies, visual engagement, and technological development etc. are confirmed as the substantial and robust factors, which enhance the BD among the students [3-12]. Among these constructs, technology-associated constructs such as RCT, MC, DC, and WRU are observed to be meaningful and substantial but not confirmed in a combined or integrated way, specifically towards BD. Contextually, medical students of different public sector universities in Egypt are not focused [9-12] despite Egyptian medical students substantially using technology for various learning purposes, such as communication, learning, and entertainment. These technological appliances support them in providing health information at hospitals and clinics and reviewing different treatments [13]. However, examining these technologies for students' BD purposes is a dire need among medical university students in Egypt [14, 15]. Based on these arguments, we raised the question:

RQ1: What is the role of technology use and digital characteristics in developing students' brain development?

The study's findings support policymakers' and universities' authorization to bring more technology culture to further nourish medical students' minds or BD. The study would assist in utilizing the DC to enhance the BD in the universities. Finally, the study outcomes would help develop a conducive learning environment, where technology and digitalization would be the top priority of students' learning for the sake of nurturing BD and cognitive skills.

2. Literature Review and Hypotheses Development

2.1 Rapid Communication Technology (RCT)

The RCT reflects the different technology-oriented communication modes that enhance and improve the student's academic performance and BD. These include commenting on Facebook,

checking on Facebook, sending text messages, multitasking, updating Facebook, voice cell phone calls, computer chat, etc. [16]. These technological appliances are of massive importance in developing BD among students. These technologies brought robust attention to the impact of technology on students' academic performance and well-being [6, 7, 12]. In the study of [17], digital technologies positively predict brain adaptation. Likewise, according to [18, 19], RCT is a positive developer of capabilities, ultimately enhancing the student's learning capacity and BD. Besides, teaching brain behavior can be improved through communication skills, which come through technology [20, 21]. Technology can also enhance cognition and well-being among children [22, 23].

2.2 Multimedia Creation (MC)

The MC has an essential contribution to academics and everyday routines. This includes creating digital video, uploading video to the Web, creating digital audio file, uploading digital images, and creating digital images [16]. These MC-associated appliances enhance performance and AI-driven platforms in education [8, 24, 25]. These assist in achieving thoughtful pedagogical targets and balancing media consumption, promoting individual learning styles [26, 27]. According to [9], digital media positively enhances BD and cognitive processes, media education, and advocacy of educational approaches for adolescents [28]. Moreover, there is excessive potential for self-directed learning facilitated by digital media and the effect of visual media on determining mental models, correspondingly emphasizing media's ability to develop problem-solving skills and critical thinking [29, 30].

2.3 Web Resource Use (WRU)

The WRU is important for academia and other sectors as well. Different individuals use this to find the facts and realities. Many use it to watch videos and listen to music online, and they use the web to explore topics in-depth for their academic performance [16]. In the study of [31], the mental development of medical students is possible through multimedia tutorials. Factors such as WRU and digital technology and WRU positively predict student cognitive development [32]. According to several scholars [33-35], WRU reduces several academic obstacles, i.e., digital inaccessibility, communication gaps, etc. The WRU and online search strategies are significant enablers of students' BD [36]. In the perception of [37], WRU and training for mental health enhance the student’s potential for online platforms, which ultimately enhances BD. Similarly, WRU positively improves the students' research experiences in the academic arena, where it enhances BD [38]. WRU is also a favorable and influential factor in improving motivation and use of online learning among college students [39, 40].

2.4 Digital Characteristics (DC)

The DC points to the digital features individuals can apply for various reasons, including enhancing their academic progress and performance. These characteristics include fast, expedient web search, multitasking while learning, and maintaining constant contact with friends while learning [16]. There is a positive connection between learning characteristics and the use of digital technology among students [16]. In the literature, the significant contribution of digital

technologies has been recognized towards cognitive development and BD [5, 10, 32]. More specifically, the empirical investigation of [41] confirms the positive effect of digital technology on identity development. Likewise, the material related to the DC, i.e., digital textbooks, animations, games, and simulations, favorably enhances learning and cognitive skills, which brings BD among the students [10, 11]. According to [42], brain activation variances in students are associated with digital learning, given the potential risks of digital media addiction. Digital tools, such as digital textbooks and animated videos, are robust in improving science literacy skills and learning outcomes [10]. According to [3], BD and students' well-being are positively affected by BD and supportive learning environments.

2.5 Brain Development (BD)

The BD underlines the individual's activities that appeal to all of their brains and help them feel more relaxed. The BD comes from technology learning and education, which they learned [43]. Several constructs and tools positively improve BD among students. These include digital technology, digital learning environment, RCT, information-seeking behavior, science literacy skills, WRU, and DC [10, 32, 41]. Among university students, digital technologies can positively enhance BD and cognitive development [32]. Likewise, BD and emotional well-being are robustly predicted through knowledge acquisition and technological development [3-5, 44]. Technology-related information such as simulations, games, animations, and digital books can improve BD by enhancing learning and skills [10, 11].

As a result, the above literature offers diverse constructs such as RCT, digital technologies, visual engagement, learning and skills, simulations, games, animations, digital books, learning strategies, MC, digital media use, DC, digital platforms, WRU, use of online learning, knowledge acquisition and technological development and motivation, etc. are the significant predictors of BD and cognitive development of the students [3-8, 10-12]. However, the literature still reveals gaps that need to be explored. The literature must include the framework for integrating RCT, WRU, MC, and digital characteristics towards BD. Moreover, context-wise, there is also a need for more literature that has not been explored in the university context of Egypt, specifically among medical university students. Based on these gaps, the researchers proposed a model (Figure 1) that integrates constructs such as RCT, WRU, MC, and DC towards BD among different public sector medical university students.

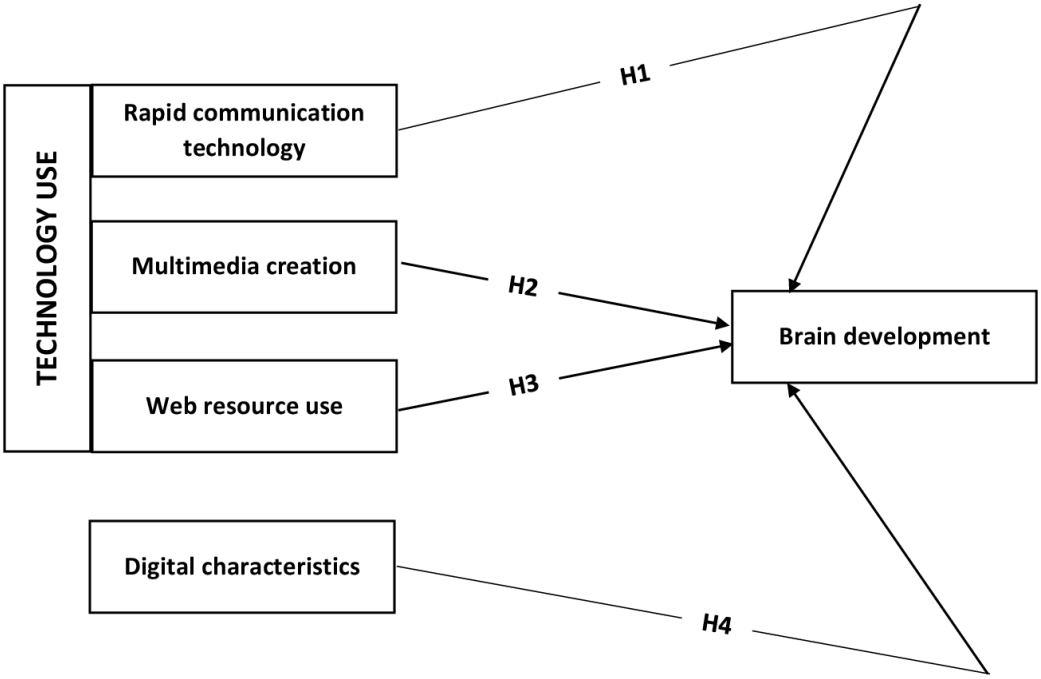

Figure 1 Model of the study.

2.6 Rapid Communication Technology (RCT) and Brain Development (BD)

Communication is necessary for BD, where technology plays a substantial role in nurturing the students' minds [45]. According to [46], e-learning environments directly connect technology learning and human brain functioning. On the other hand, [47] warns about the potential social and emotional costs of excessive screen time on adolescent BD. In the classrooms, portable brain technologies integrate neuroscience and the BD of students [48]. In the study of [23], promoting natural learning affects technology and the interconnectedness of education and the brain. Children's cognition and well-being are enhanced through technology [22]. Well-known scholars like [20, 21] confirm technology's efficiency and transformative potential in teaching brain-behaviour relations and impacting societal aspects beyond education. [17] confirms the generational differences in brain adaptation to digital technologies among millennials. Technology integration positively enriches BD and academic achievement [19]. In the assessment of [18], brain-computer interfaces positively enhance learning strategies and student capabilities. Recently, scholars like [6, 7, 12] have brought attention to the impact of technology on students' well-being and academic performance and found it positive.

Consequently, the literature offers a positive connection between RCT and BD. However, in the presence of other constructs, such as WRU, DC, and MC, these need confirmation. Therefore:

H1. RCT has a positive effect on students' BD.

2.7 Multimedia Creation (MC) and Brain Development (BD)

The MC is a substantial and positive predictor of BD. It significantly impacts arts instruction and cognitive, social, and emotional development, which underlines the contribution of creativity in stimulating different areas of the brain [49]. [9] suggests the importance of the allure of digital

media for adolescents. These visually engaging and interactive content can engage and shape the developing brain. Brain-based learning principles are positively enhanced through cognitive processes, media education, and advocacy of educational approaches [28]. According to [29] and [30], there is excellent potential for self-directed learning facilitated by digital media and the influence of visual media on shaping mental models, respectively, highlighting the media's standing in nurturing critical thinking and problem-solving skills. These perceptions are completed by considerations of the risks of excessive screen time and digital media use [8] and the integration of AI-driven platforms in education [24, 25]. These underline the need for balanced media consumption and thoughtful pedagogical approaches considering brain development stages and individual learning styles [26, 27].

As a result, the MC is BD's influential enabler, confirmed earlier in diverse students. However, medical university students in Egypt need further validation. Thus:

H2. MC has a positive effect on students' BD.

2.8 Web Resource Use (WRU) and Brain Development (BD)

Digital technologies contribute to developing several features of education and mental health support among university students. Nonacademic mental health support is also prominent for doctoral students who need accessible resources, especially WRU [50]. According to [37], training for mental health and web-based education transfer among student-athletes underlines the great potential of online platforms. According to [38], a brain map can improve student research experiences, imitating the integration of digital resources into academic endeavors. Likewise, [31] establishes the effect of multimedia tutorials on medical students' retention of embryonic development, underscoring the assistance of interactive digital learning tools. The neuroscience of the university classroom confirms the positive effect of digital technology and WRU on student cognitive development [32]. In the study of [35], digital accessibility helps overcome mental obstacles in employment practices. The websites positively supported the communication of mental health support to college students, especially in the COVID-19 era [36]. Researchers like [33, 34] evaluated student searching behavior and online search strategies and confirmed the positive effect of WRU on students' BD. As per the systematic review evaluation of [51], mental health-related digital use is supportive of the growing reliance on digital platforms for mental health support among university students. Likewise, the studies of [39, 40] recognized the prominence of WRU in developing the motivation and use of online learning and self-help mental health resources among college students.

Consequently, WRU supports students from different angles and provides significant information for them to grow their careers. In the context of medical university students in Egypt, we expect:

H3. WRU has a positive effect on students' BD.

2.9 Digital Characteristics (DC) and Brain Development (BD)

Encircling various technologies and platforms, DC plays an essential role in determining BD in several contextual settings. Digital technologies always remained favorable in cognitive development, specifically among university students [32]. In the perception of [42], brain

activation variances in students affianced in digital learning, given the potential risks of digital media addiction. Digital tools, i.e., digital textbooks and animated videos, are robust in improving science literacy skills and learning outcomes [10]. Likewise, digital simulation tools indirectly affect the student's well-being and BD through supportive learning environments [3]. These findings are reinforced by several researchers like [4, 5], who provided the importance of DC in developing brain health and emotional well-being. Knowledge acquisition and cognitive development are shaped by digital environments and information-seeking behaviour [44]. According to [41], there is a psychological impact of digital technology on identity development, which in turn can impact BD and mental health consequences. The DC material, such as simulations, games, animations, and digital textbooks, positively reinforces the effectiveness of learning and cognitive skills, which enhances BD [10, 11].

Based on the positive connection between DC and BD, we expect a further positive connection between DC and BD in medical university students of Egypt. Therefore:

H4. DC has a positive effect on students' BD.

3. Methods

3.1 Approach and Respondents of the Study

We applied the quantitative approach, which is the best for examining social, management, and business issues [51]. In social, management, medical and business research, this approach is common and most frequently applied to explore problems [7, 10, 52]. In the dimensions such as digital technology, cognitive development, and BD, etc. [4-7, 12].

We targeted the different medical universities in Egypt, where we collected the data from university medical students. Medical students use technology for various purposes, such as communication, learning, and entertainment. Technology supporting pervasive systems such as health information technology and mobile learning at hospitals can be cohesive into clerkship syllabuses [13]. Investigating medical students' needs is essential for enhancing the efficiency and effectiveness of their education [13]. Examining issues such as students' BD through technology use and digital characteristics among medical students is essential for mental health awareness and promoting a healthy balance between technology use and other activities [14, 15].

3.2 Survey Reliability and Validity

Before moving to collect the large-scale data, we ensured the reliability of the survey by conducting a pilot study. In the piloting, we gathered 18 samples to ensure internal consistency among the items. It was ensured through Cronbach's alpha (α), which is found to be greater than 0.70 for the majority of factors except a few, along with an overall reliability of 0.810. Moreover, we also confirmed the factor loading to ensure the connection of the items with their related factor. The loading scores are also found to be greater than 0.70 (Table 1).

Table 1 Pilot study outcomes.

Construct	No. of items	Alpha (α)	Item code	Loadings
Rapid communication technology [RCT]	7	0.827	rct1	0.702
			rct2	0.682
			rct3	0.733
			Rct4	0.492
			rct5	0.803
			rct6	0.732
			rct7	0.798
Multimedia communication [MC]	5	0.783	mc1	0.782
			mc2	0.392
			mc3	0.827
			mc4	0.847
			mc5	0.877
Web resource use [WRU]	4	0.719	wru1	0.776
			wru2	0.805
			wru3	0.754
			wru4	0.744
Digital characteristics [DC]	3	0.733	dc1	0.731
			dc2	0.798
			dc3	0.755
Brain development [BD]	5		bd1	0.788
			bd2	0.773
			bd3	0.803
			bd4	0.788
			bd5	0.739

Source: Estimated by the researchers.

Moreover, we ensured the validity of the questionnaire in terms of the language barrier (as the questionnaire is administered in English) and formatted it through respondents' feedback in the form of comments. As a result, we did not find any severe comments regarding the language barrier and the questionnaire's format. Hence, it is found valid.

3.3 Data Collection Methods

The researchers applied offline and online data collection modes to collect the cross-sectional data. The offline data were gathered through personal visits to the different public sector universities of Egypt, where we initially contacted the deans and directors to get permission to enter into the respondents' classes. We applied a convenience sampling technique to reach respondents while quickly consuming minimum resources. Similarly, the online data was collected through emails, medical students' WhatsApp groups, and Facebook pages. We took care of the ethical values of respondents and sought permission to participate in the study. We further ensured their privacy and discretion when using their responses. After that, we get a signed consent form from them. In this way, we gathered 328 valid cases for the final analysis.

3.4 Measures

The survey questionnaire items are derived from the literature, and we adopted the items from [16] for RCT, MC, WRU, and DC. More specifically, RCT measured seven items. The sample item for RCT is "Technology comment in Facebook". We evaluated MC on five items, with the tester item as "multimedia creates digital image". Moreover, we gauged WRU on four items, with sample content as "Use the web to find fact". Likewise, we assessed DC with three items: "Fast expedient Web search". Finally, we evaluated the BD with five items borrowed from the study [43, 53]. The sample item of the scale is "Learning about technology makes my brain more relaxed in getting an education." We gauged all the items on a five-point Likert scale: "strongly agree to disagree strongly."

4. Analysis and Results

4.1 Measurement Model

Concerning the measurement model, as presented in Table 2 and Figure 2, the researchers ensured the loadings, the composite reliability (CR), and the average variance extracted (AVE). According to [54], the loading values should exceed or >0.70, AVE's >0.50, and CR >0.70. In this study, most items appeared with acceptable values (>0.70), while a few items, such as rct4, mc2, and bd3, did not appear with the required values. Likewise, the values of CR (>0.70) and AVE (>0.50) are also found to be within acceptable ranges [54, 55]. Moreover, the internal consistency among the items for every construct is found to be fair (>0.70) [54].

Table 2 Measurement model.

Construct	Code	Loadings	CR	AVE	α
Rapid communication technology [RCT]	rct1	0.873	0.937	0.713	0.783
	rct2	0.870			
	rct3	0.853			
	rct5	0.844			
	rct6	0.831			
	rct7	0.793			
Multimedia communication [MC]	mc1	0.882	0.912	0.722	0.828
	mc3	0.869			
	mc4	0.827			
	mc5	0.818			
Web resource use [WRU]	wru1	0.871	0.903	0.700	0.850
	wru2	0.855			
	wru3	0.832			
	wru4	0.787			
Digital characteristics [DC]	dc1	0.833	0.843	0.642	0.839
	dc2	0.807			
	dc3	0.763			
Brain development	bd1	0.853	0.890	0.670	0.799

[BD]	bd2	0.831
	bd4	0.804
	bd5	0.785

Deleted items = rc14; mc2; bd3.

Source: Authors' own estimation.

Note(s): AVE = average variance extracted values; CR = composite reliability; α = Cronbach's alpha.

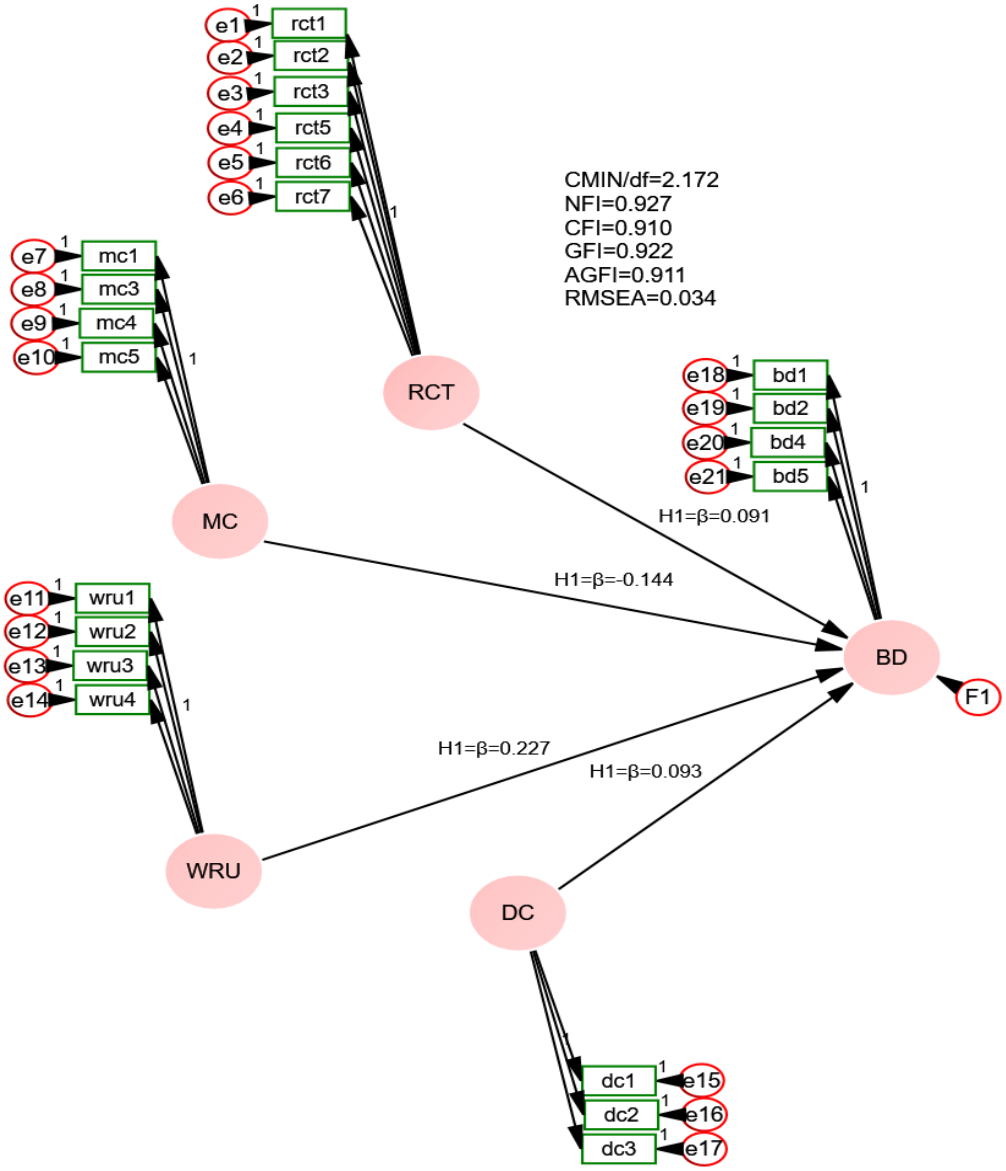

Figure 2 Path analysis. Source: Estimated by the researchers. Note(s): RCT = rapid communication technology; MC = multimedia creation; WRU = web resource use; DC = digital characteristics; BD = brain development.

The researchers also confirmed the discriminant validity (DV) to gauge the extent of distinctness of the construct [54]. As mentioned in Table 3, the criteria of [56] were set out for DV insurance pursuing the [54] with support of the square root of AVE values convergence. As a result, the researchers observed a correlation between the exogenous variables less than 0.85,

which ensured the satisfaction of the DV [54].

Table 3 Discriminant validity.

Variables	BD	RCT	MC	WRU	DC
BD	**0.618**				
RCT	0.313	**0.084**			
MC	0.221	0.421	**0.594**		
WRU	0.223	0.102	0.033	**0.484**	
DC	0.078	0.155	0.189	0.167	**0.652**

Note: "Diagonals represent the square root of the AVE while the other entries represent the correlations".

Source: Authors' calculations.

4.2 Structural Model

The researchers used Analysis of Moment Structures (AMOS) version 26.0 to analyze the data. Before testing the hypotheses, the researchers observed the model's fitness, and all the model fit indices were within the acceptable ranges [54] (Table 4). As presented in Table 5 and Figure 2, the results show the acceptance of H1, where rapid communication technology positively affects brain development (H1 = β = 0.091; $p < 0.01$). The analysis also demonstrates multimedia creation's negative effect on brain development, which rejected the H2 (H2 = β = -0.144; $p > 0.01$). Moreover, the impact of web resource use on brain development is also positive (H3 = β = 0.227; $p < 0.01$). Hence, H3 is accepted. Finally, digital characteristics are found to be a positive predictor of brain development, which accepted H4 also (H4 = β = 0.093; $p < 0.01$).

Table 4 Model fit indices [achieved vs required values].

CMIN/*df* = 2.172	NFI = 0.927	CFI = 0.910	GFI = 0.922	AGFI = 0.911	RMSEA = 0.034
[<3]	[>0.9]	[>0.9]	[>0.90]	[>0.90]	[<0.05]

Notes: "CMIN = χ^2/chi-square/*df*; *df* = degrees of freedom; NFI = Normed Fit Index; CFI = Comparative Fit Index; GFI = Goodness-of-Fit Index; AGFI = Adjusted Goodness-of-Fit Index; RMSEA = root mean square error of approximation".

Source: Authors' own calculations.

Table 5 Path results.

H.No.	Proposed effects	Std. (β)	SE	CR	p-value	Interpretation
H1	Rapid communication technology → Brain development	0.091	0.026	3.532	0.000	Supported
H2	Multimedia creation → Brain development	-0.144	0.107	1.338	0.181	Not supported
H3	Web resource use → Brain development	0.227	0.061	3.699	0.000	Supported

H4	Digital characteristics → Brain development	0.093	0.023	4.090	0.000	Supported

Note(s): SE = standard error; CR = critical ratio; p = significance level at < 0.05.

Source: Authors' own estimation.

5. Discussion

The study proposed investigating the effect of technology use and DC on BD among Egypt's different public sector medical university students. The results of the study confirmed a positive impact of RTC on BD. These outcomes are in line with several researchers like [6, 7, 12, 46-48], who attain the same outcomes. These results reflect that the medical students of Egypt use different technology applications, such as Facebook, computers, cell phones, etc., to make their studies more accessible. They exchange or share their medical problems and use Facebook pages and computer chat. These sources make their fast modes of communication and enhance the brain's capacity to understand medical accessories and apparatus.

The study suggests an adverse effect of MC in developing BD, which contradicts domain literature [24, 25, 27, 29, 30]. These results demonstrate that the MC does not support medical students in creating and generating digital images and videos. MC did not assist them in uploading videos on the web. It also has no support for creating digital audio files and uploading digital photos online. These negative results further suggest that MC hinders getting a quality education with no easy way to understand with image view. The image view is the most complex and adverse way to comprehend material.

On the other hand, the study's results also highlight the positive effect of WRU on BD. These findings align with a wealth of scholarly research that has confirmed the positive impact of WRU on BD [31, 34, 35, 38, 40, 51]. These positive results underscore that students can refresh their minds by using web resources to study. They can watch online videos, listen to music, and explore their topics and academic assignments more comprehensively, thereby reducing study stress and pressure.

Finally, DC is the significant predictor of BD, reinforced by the domain literature [3-5, 10, 32, 41, 42]. The results show that the web search is convenient for them when contacting family members and friends. It helps them maintain and sustain their contacts. They finish multiple learning tasks through DC. The BD is relaxed through the different MC activities. They happily get an education through the sage of digital technology. Their brain is anxious when they do not use technology-related activities.

6. Conclusion

The study's overall results suggest that RCT, WRU, and DC positively affect BD. On the other hand, MC harms BD among students at different public medical universities in Egypt. These results suggest that technology is prominent in developing students' cognitive and mental development.

Concerning practical implications, the study would offer guidelines to policymakers and university planning authorities to design policies and plans that enhance students' BD and mental relaxation. The study would encourage medical universities to adopt and reinforce student digital access. By employing these technologies, medical students would reduce the burden and pressure of surveys through the ease and accessibility of technological appliances. Moreover, the findings

confirmed that the RCT, WRU, and DC are the best predictors of BD; therefore, in medical education specifically, technology substantially supports students in making their minds relax and feel relaxed. They have a dire need for technology; when they do not use it, they feel uncomfortable and unrelaxed. However, there is little need to bring improvement in the MC, as it does not have enough role in enhancing BD.

Concerning theoretical implications, the study would favor developing a more conceptual model pursuing the study's findings. From a theoretical perspective, this study would assist in understanding the concepts of technology use, MC, WRU, DC, and RCT towards BD. Besides, the study would offer empirical insights that may enrich the standing of quantitative methods with cross-sectional data. The study would support researchers conducting more studies pursuing these methods in developing contexts. Finally, the study's results would contribute to and enrich the depth of the literature, specifically from empirical evidence of a developing context.

The study has certain limitations. The study's approach is only quantitative. The researchers collected only one shot of cross-sectional data. The study is limited to a few constructs, such as RCT, MC, DC, and WRU, and it is intended to investigate the BD. Context-wise, the study is limited to only public sector medical universities of Egypt, where medical students were targeted as the study's unit of analysis. The study is restricted as it did not apply theory to underprop the study's conceptual framework. Finally, the overall conclusion of the study is based on 328 samples.

Researchers may consider the mixed-method approach to test the same model in the future. Future studies may consider longitudinal data to validate further conclusions. Moreover, our organizations, such as SMEs and education, may be targeted. Other diverse respondents, such as teachers, professors, and administrative staff, may be selected as targeted respondents for future studies. The concerned theories may be applied to underpin the study's conceptual framework. Finally, the sample size may be enhanced to get more suitable results.

Acknowledgments

The researcher sincerely thankful to the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia for providing the funds. The researcher also appreciates the respondents who gave their precious time for providing their valuable responses.

Author Contributions

Abdelwahed NAA developed the conceptualization framework, hypotheses of the study, analyzed the data and discussed the results in the light of literature. Ramish MS developed the methods and write-up of the manuscript. Both authors accepted the final version after revisions.

Funding

This work was supported by the Deanship of Scientific Research, Vice Presidency for Graduate Studies and Scientific Research, King Faisal University, Saudi Arabia [Project Grant No. KFU 241049].

Competing Interests

The authors have declared that no competing interests exist.

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