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Integrating technology-mediated learning in biology education (histology): A systematic literature review

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Abstract

Leveraging technology is an integral component of any 21st century learning. Researchers and practitioners are still working on ways to improve the impact on student learning with the help of technology as learning tools. Therefore, this study was carried out to study the effects of integrating technology-mediated learning in biology education using systematic literature review (SLR). Finding from the analysis of selected literatures found that the integration of technology-mediated learning has a significant positive impact on students' academic achievement and learning experience. Further research can be carried out by investigating the impact of technology-mediated collaborative learning on learning experience and academic achievement in histology. Several advantages and features of technology-mediated learning are identified through the classification of aspect in terms of learning methods, learning approaches and delivery methods.

Keyword: technology-mediated learning, mobile application, smartphone application, histology, biology education

INTRODUCTION

In the teaching and learning process, information and communication technology (ICT) plays a critical role. Nowadays, the majority of the population has easy access to the internet via personal computers, smartphones, watches, and other gadgets. As a result, learning environments and methods of acquiring knowledge have evolved, and multitasking has become ubiquitous.

A. ICT in education

Several studies in the literature explore the role of mobile ICT in the education system. [1] reported that the use of ICTs in the classroom has a positive or neutral influence on both teachers and students. The large-sample study involved 4461 schools, 10691 teachers and 102231 students from Austria. Not only students, but most teachers, are enthusiastic about using ICTs in the classroom, despite the fact that many teachers find it challenging to integrate them [2].

[3] examined the teachers' reactions to challenges posed by the use of ICT in educational activities in Singaporean schools. The study involved two primary and two secondary schools. First-order and second-order barriers were identified. First-order barriers are not related to teacher's person. The study revealed that teachers had the difficulty in keeping lessons to the customary 40-45 minutes when ICT is used; the lengthy time required to set up ICTs at the start of the session; the dissatisfaction created by computers that are obsolete or insufficient in number. For second-order barriers, some teachers believed that conventional methods were faster and more efficient than ICT; others saw ICT as a threat to traditional education; and

still others were hesitant to communicate with their colleagues the challenges they encountered when teaching using ICT [3].

Meanwhile, [4] investigated 70 biology teachers on why the installation of computers and laboratory equipment in classrooms was not as successful as expected. The biology teachers showed positive response towards the willingness of using the internet and core Microsoft application in preparing classroom materials; and the willingness of using of computer programs, presentations and virtual laboratories, although some neglected such tools, due to the insufficient skills and the size of curriculum. The study revealed that teachers generally showed a negative response and refused to use ICT especially when in revolved around gamification and programming [4].

Another study in England explored the difficulties related to ICT-mediated learning. [5] mentioned that the knowledge transfer was not working correctly with the tools, despite the fact that ICT-supported school education may be improved with the creation of these tools. In general, this strategy is more difficult to apply in domains, especially in biology, where memorising is a common pedagogical practise [6].

Previous research indicates that the presence of various ICT, as well as both teachers' and students' positive attitudes, open up new and promising possibilities for future teaching techniques. However, much more work must be done to precisely describe ICT-mediated teaching methods that may support the teaching and learning processes.

B. ICT in Biology Education

The association and role of ICT in biology education is difficult to assess precisely; however, it is known that technology acts as a catalyst, resulting in a shift in teaching style, learning methods, and information availability [7]. In the case of biology education, the common benefits of employing ICT include facilitating visualization, speeding information transfer between teachers and students, eliminating time limits, contributing to repeatable practices, boosting collaboration, and assisting in overcoming geographic distances [2].

In facilitating the education of biological cell and photosynthesis, the usage of visuals application in class was deemed beneficial by 37 teachers who participated in the study [8]. Computer-mediated stimulation (CMS) applications can also improve students' understanding of the Cell Theory [9]. Using computer animations, students can have a better understanding of abstract Molecular biology ideas and processes [10]. Not only are computers, websites, blogs, microphones, interactive boards, digital films, online media, and digital games popular for integrating ICT and biology lectures, but smartphones, iPods, iPads, and other equipment can be successfully employed to increase students' academic achievement [11]. In general, these technologies help to improve biology study as a whole [12].

Based on the examples above, it is clear that ICT-mediated biology teaching was beneficial in a variety of biology classrooms; whether it is lecture, tutorial, or laboratory work. Teaching of biology could be significantly more effective and fun for the 21st century generation by upgrading ICT-mediated teaching methodologies and developing more and more customised programmes or tools for biology teaching. The most recent tool is not always superior; rather, it serves as a supplement to the traditional method of instruction [13]. Researchers can either search for, innovate or invent applications that meet educational needs [14].

Because of the ever-changing technological landscape, basic science teaching methods must be innovative [15]. For some, elements of game-based is incorporated into the teaching method. Gamification enhances student learning by providing additional scaffolding [15]. The effects of the web-based Virtual Microscopy platform on students' academic performance are cumulative and synergistic [16].

C. Summary for ICT researches

[17] summarize the positive and negative impact on student achievement in academic using meta-analysis of various technology studies. There is, however, in some of these researches, there is evidence that technology-mediated learning is less successful or ineffective when the learning objectives are ambiguous and the focus of technology use is diffuse [17]. Of late, many researchers reported a positive effect of using technology in general [13], [16], [18]–[20], but some studies found no effect. Some experts think that technology has almost little influence or has a negative effect on learning and education, but others believe that using technology in learning and education is beneficial. Some have observed a discrepancy between

claims and advances brought about by educational technology [21]–[23]. [23] reported that there is no evidence yet that teachers and students would have benefitted from using computers in terms of student participation in schools. Because there is no agreement on the use of technology in biology education, and particularly in laboratory practicals, hence, it is necessary for researchers to bridge the gap left by previous studies.

METHODOLOGY

This study is based on a systematic literature review on the last five years, from the year 2017 to the year 2021. The most recent material has been presented in order to contribute to the continuing debate concerning the role of technology in the changing educational paradigm. The study primarily focuses on the technology-mediated teaching and learning method that makes it easier for learners to obtain a better education. Systematic Review and Meta-Analysis (PRISMA) guidelines was used to analyse the accumulated articles. The four steps in PRISMA are a) identification, b) screening, c) eligibility, and d) inclusion. This technique was employed as it is able to guide researcher to synthesis relevant article journals. Figure 1 outlines the steps taken in PRISMA, which are adapted and altered from [24].

A. Identification

Literatures had been extensively searched from the databases; *ERIC*, *ProQuest* and *Google Scholar*. Keywords such as "technology-mediated learning", "mobile application", "smartphone application", "histology", and "biology education" were used for the identification purpose. Overall, 88 article journals were found at this stage.

B. Screening

The scope of the screening is confined to 1) learning using technology tools such as computer, laptop smartphone, iPad, and tablet, 2) learning through software application such as Kahoot, WhatsApp and Padlet, 3) learning through gamification. Preference is given to the subject matter of histology instead of biology education, and laboratory work instead of lecture or tutorial. And then, the repeated articles removed by title and abstract reading. After screening, 7 article journals not adhering to the criteria of research and 39 repeated article journals are removed, leaving only 25 article journals.

C. Eligibility

25 article journals were screened thoroughly, focusing on the title, abstract, methodology, findings, and discussions to make sure it is in line with the scope and objective of the study. 10 article journals are removed as it does not describe the integration of technology in learning (8 articles), and poorly discussion on results of the study (2 articles).

D. Inclusion

Finally, only 15 article journals adhering to the chosen criteria are selected for this study. This qualitative document selection has been done by the following the checklist of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) [25].

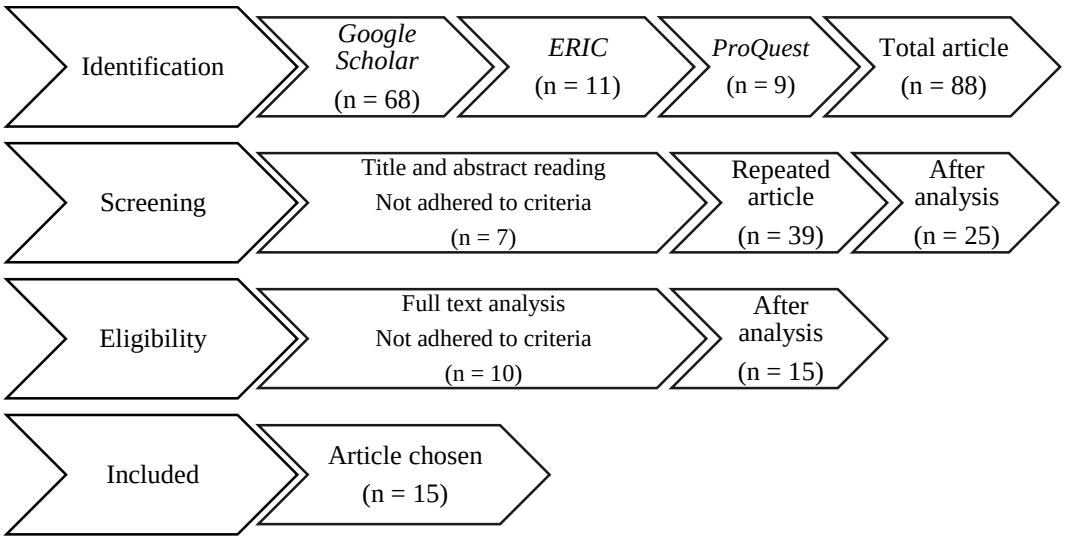

Figure 1. Adapted and altered process of article selection from [24]

RESULTS OF THE STUDY

A. Summary of the Selected Article Journals

The 15 article journals are analysed into various categories; study (year), sample size, research design, major findings, comments, and sources. The results are summarized into Table 1.

Table 1. Summary of the selected article journals

Study (year)	Sample Size	Research Design	Major Findings	Comments	Sources
[26]	45 students	Qualitative and quantitative mixed approach on primary data from students	Mixed reality mobile application was functional, usable, efficient, portable and accepted to support to learning of anatomy	Mixed reality mobile application as a technology tool	International Journal of Multidisciplinary Research and Explorer
[27]	20 undergrad students	Quantitative approach on primary data from students	There is no effect of the ICT-based CWPT model on student creativity Student creativity in learning ICT is affected by motivational influence There is no interaction between the model and the motivation to learn ICT with student creativity	The role of motivation has a high impact in influencing student creativity	BIODIK
[15]	215 undergrad students	Qualitative oriented quantitative mixed approach on primary data from students	Support the use of gamification in the teaching of histology Gamification provides additional scaffolding for students learning	Collaborative Kahoot-mediated has a higher impact than individual Kahoot-mediated Kahoot-mediated strengthened the students' positive attitudes toward histology No control group	BMC Medical Education
[28]	250 students divided to team of 5-8 (20 teams selected for	Qualitative approach on primary data from students	Interactive touch-screen monitor had many positive impacts on students and instructors' perceptions	Transform traditional plant anatomy lab into collaborative activity Technology as a useful addition to, though not a	Journal of Biological Education

	group interview)			substitute for, a traditional microscope lab No control group	
[19]	62 students	Quantitative approach on primary data from students	CAIP significantly improved students' achievement in practical Gender had no considerable influence on the achievement in practical	Females have more advantage in the achievement in practical but no significance difference between gender	Cypriot Journal of Educational Sciences
[29]	122 undergrad students	Quantitative approach on primary data from students	NFC technology is simple, favourable, user-friendly and versatile tool for Histology	Using Near Field Communication technology as a support in the teaching of histology No control group	Wireless Communications and Mobile Computing
[16]	1313 undergrad students	Qualitative and quantitative mixed approach on primary data from students	Web-based Virtual Microscopy platform effects are cumulative and synergistic on students' academic performance VM platform is strongly perceived as an effective teaching tool	Combination of virtual and light microscopy remains the most preferred approach	Anatomical Sciences Education
[20]	250 undergrad students	Quantitative approach on primary data from students	The use of WhatsApp complements traditional teaching as it is feasible, effective and student-friendly	Use of WhatsApp is acceptable tool in teaching histology Use of WhatsApp is feasible as smartphone are readily available No control group	Journal of Education and Health Promotion
[30]	108 undergrad students	Quantitative oriented qualitative mixed approach (narrative) on primary data from students	More significant for part-time students to visualise via electronic means for histology	E-learning approach is a preference by the part-time students in studying histology	Science and Technology
[31]	100 students	Qualitative and quantitative mixed approach on primary data from students	Practical video (V-lab) accompanied by manual as alternative to facilitate biology practicals	Positive perception of using practical video and manual by students	Jurnal Pendidikan Sains & Matematik Malaysia
[13]	39 undergrad students	Quantitative approach on primary data from students	No overall difference between treatment and control group. Newest tools are not always better but rather act as complement to the traditional instruction method	Using interactive cloud-based classroom response system (CRS) to identify misconceptions and provide feedback.	Anatomical Sciences Education
[18]	82 undergrad students	Quantitative approach on primary data from students	Support the use of gamification in the teaching of histology	Vast majority of students use gamification to study and positively perceive the learning method No control group	International Journal of Morphology
[32]	6 students	Qualitative approach on primary data from students	Padlet has potential in enhancing student's engagement	Positive perception of using Padlet is going to be retained and negative perception has to be improved	Jurnal Pendidikan Sains Dan Matematik Malaysia
[2]	58 students	Quantitative approach on primary data from students	Edmodo and ICT enhanced students' motivation and academic achievement in biology	Edmodo usage promotes enthusiasm, making lesson more appealing and facilitate content delivery	Problems of Education in the 21st Century
[14]	82 undergrad students	Quantitative approach on primary data from students	Smartphone application benefited student in histology	BAND application is not intended for educational used Need to invent application that's fulfil the need of education	Anatomy & Biological Anthropology

B. Thematic Analysis of the Intended Outcomes from Incorporating Technology in Learning

Many researchers reported positive effects of technology-mediated on learning, either on academic achievement or learning experiences. Learning experience is further classified into a) perception, b) knowledge enhancement, c) skill enhancement, and d) motivation. The classification is adapted, deduced and reclassified from [33]. The results are summarized into Table 2.

Table 2. Thematic analysis of outcomes from the researches

Study (year)	Academic Achievement	Learning Experience			
		Perception	Knowledge Enhancement	Skill Enhancement	Motivation
[26]		*			
[27]					*
[15]	*	*	*	*	*
[28]		*	*	*	*
[19]	*				
[29]	*	*	*		
[16]	*	*	*		
[20]	*	*	*	*	
[30]	*		*		
[31]		*			
[13]	*	*	*		*
[18]	*	*	*		*
[32]		*			
[2]	*	*			*
[14]		*			

C. Analysis of Technology-mediated Learning Method, Learning Approaches and Delivery Method

Teaching and learning technologies are becoming more sophisticated as technology advances. Modern technology assists teachers and students who are equipped with cutting-edge technology. Experts offer some learning methods that support old methods while transforming current methods through the integration of technology. This study has identified six types of methods as input of learning such as student created content, collaborative learning, active learning, blended learning, flipped learning, and components of technology focused learning.

The following researches that focused on technology-based learning approaches were discovered by this study. The major learning approaches are electronic learning (e-learning), digital learning (d-learning), mobile learning (m-learning), and ubiquitous learning (u-learning). Technology-mediated delivery methods are via lecture, tutorial or laboratory work. The results are summarized in Table 3.

Table 3. Analysis of technology-mediated learning method, learning approaches and delivery method employed in the researches

Study (year)	Technology-mediated Learning Method	Technology-mediated Learning Approaches (d/e/m/u)	Technology-mediated Delivery Method
[26]	Blended learning	m-learning d-learning	Lecture
[27]	Collaborative learning	u-learning	Tutorial
[15]	Active learning Collaborative learning	e-learning	Lecture Lab
[28]	Student created content Active learning Collaborative learning	m-learning u-learning	Lab
[19]	Components of technology focused learning	e-learning	Lecture

[29]	Active learning	m-learning	Lab
[16]	Active learning Flipped learning	e-learning m-learning	Lab
[20]	Student created content Active learning Collaborative learning	m-learning	Lab
[30]	Blended learning Flipped learning	d-learning e-learning	Lecture Tutorial
[31]	Blended learning Flipped learning	d-learning	Lab
[13]	Active learning Collaborative learning	e-learning	Lecture Lab
[18]	Active learning	d-learning m-learning	Lab
[32]	Student created content Collaborative learning	d-learning	Lecture
[2]	Student created content Collaborative learning Blended learning	d-learning e-learning	Lecture Tutorial
[14]	Active learning Collaborative learning	m-learning	Lab

DISCUSSIONS

This section deals with the research results in two main parts; effects of technology-mediated learning on academic achievement and learning experience, and b) technology-mediated learning method, learning approaches and delivery method.

Based on the systematic literature review, this study able to detect the positive effect of technology-mediated learning in biology education especially on the subject matter histology. The positive effects can be observed under academic achievement or learning experience by the students. There are many researches that supported the integration of technology in learning on academic achievement and gave positive effects [13], [16], [18]–[20]. [19] depth in further and reported that females have more advantage in the achievement in practical assessment after integration of technology, but no significance difference between the gender.

On the other hand, students' learning experience can be classified using perception, knowledge enhancement, skill enhancement, and motivation. The reclassification is adapted from [33] which reported that Padlet in intensifying engagement, enhances learning in students. [32] suggested that positive perception of using Padlet is going to be retained and negative perception has to be improved. It is further supported by the study carried out by [28] on the interactive touch-screen monitor during histology practical. The integration had many positive impacts on students' perceptions. It transform traditional plant anatomy lab into collaborative activity [28]. Students in deed will learn the collaborative skills as well as knowledge enhancement. The concept on technology-mediated collaborative learning should be given significant priority in 21st century as this learning method is crucial in biology education. There still a gap in the literatures as limited researches are done in this field of study. [15] explored on collaborative Kahoot-mediated in histology learning which gave a higher impact than individual Kahoot-mediated. Kahoot-mediated strengthened the students' positive attitudes toward histology. Besides that, motivations play important aspect in affecting students' learning experience.

There are many limitations in the studies mentioned in this systematic literature review as there are no control group for the studies done. This is observed in the researches done by [15], [18], [20], [28], [29]. Hence, there is possibility for further research to be carried out in supporting the motion of technology-mediated learning.

The second part describes the technology-mediated learning method, learning approaches and delivery method which uses secondary data. Figure 2 shows the model of leveraging technology-mediated learning which are adapted from [34].

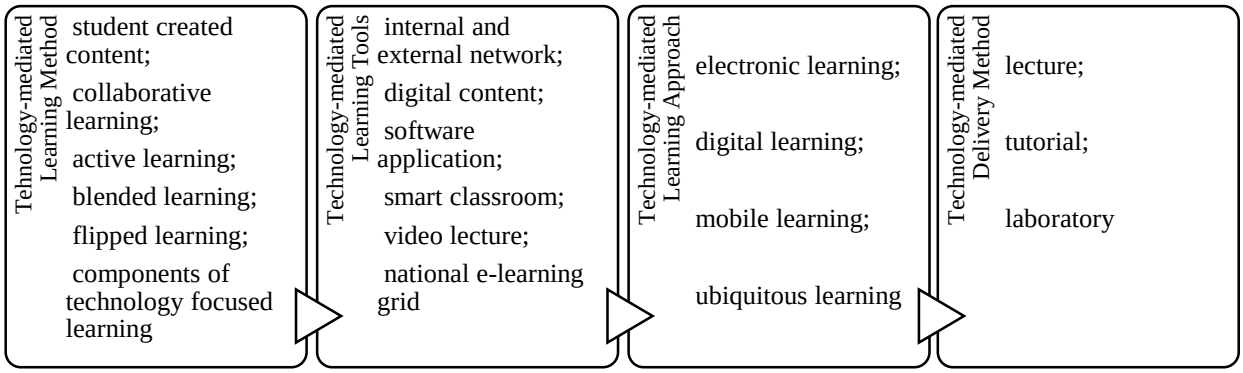

Figure 2. Model of leveraging technology-mediated learning adapted from Islam Sarker et al. (2019)

There are six ways of technology-mediated learning methods which are revealed from the systematic literature search result in Table 3. This study has identified six types of methods as input of learning such as a) student created content, b) collaborative learning, c) active learning, d) blended learning, e) flipped learning, and f) components of technology focused learning.

This study also identifies the four primary types of learning approaches associated with technology. They are a) electronic learning, b) mobile learning, c) digital learning, and d) ubiquitous learning. U-learning (Ubiquitous learning) is a relatively recent idea that can be applied to a variety of disciplines. U-learning is the most advanced kind of mobile learning, having moved from e-learning to m-learning and m-learning to u-learning. It aids in acquiring knowledge from a ubiquitous learning environment at the right time, in the right place, and in the right way [34]. D-learning is a technology-mediated learning approaches that allows learners to control their studying time, place, and path. It is, in fact, a combination of digital content, technology, and instruction.

Besides that, this study delves deeper into the implementation of technology-mediated delivery modes, focusing on lecture, tutorial, and laboratory work. The lecture is an effective and conventional mode of learning delivery. Though the approach of teaching and learning through lecture is widely acknowledged, several modifications are required to reap the full benefits. Instead of a top-down approach, effective learning requires two-way communication between teacher and learner. Technology could serve as a link in this two-way communication channel. Sometimes, many schools use a flipped classroom, which is a hybrid method that combines a tutorial with conventional class lectures. It is now widely accepted in many countries. A laboratory is a venue where students can receive hands-on experience with theory. In the laboratory, several scientific discoveries are investigated, especially for subjects related to science.

CONCLUSION

In this study, a systematic literature review had been carried out to explore the impact of integrating technology in biology education (histology). Based on the analysis of the 15 previous researches done, a general conclusion was made. There is a significant positive impact on the academic achievement and learning experience of the students in terms of perception, knowledge enhancement, skill enhancement, and motivation by integrating technology in the teaching and learning process. This study has identified six types of methods as input of learning such as a) student created content, b) collaborative learning, c) active learning, d) blended learning, e) flipped learning, and f) components of technology focused learning. This study also identifies the four primary types of learning approaches associated with technology. They are a) electronic learning, b) mobile learning, c) digital learning, and d) ubiquitous learning. This study delves deeper into the implementation of technology-mediated delivery modes, focusing on lecture, tutorial, and laboratory work. In order to maximise the full potential of technology-based learning methods, ICT should be integrated at all levels of curriculum development, learning processes, and delivery [34]. Innovation and reform are required to ensure better education through ICT integration.

All of the researches chosen for this systematic review are primarily concerned with histology undergraduate students as respondents. Primarily because, my focus of my proposed study is on the sixth-form students in histology laboratory work. My suggested topic is the effectiveness of using visual

communicative platform Celebrate® application in technology-mediated collaborative learning for accessing learning experience and academic achievement in sixth-form histology practicals. Hopefully, the additional research mentioned in this study will be thoroughly investigated in the context of our country's biology education.

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