Journal of ICT in Education (JICTIE)
ISSN 2289-7844 / 9 / 1 / 2022 / 86-99

Integrating Technology-Mediated Learning in Biology Education (Histology): A Systematic Literature Review

Teoh Chern Zhong, Muhamad Ikhwan Mat Saad*, Che Nidzam Che Ahmad

Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris;
chernzhong85@msn.com, {ikhwan.saad, nidzam}@fsmt.upsi.edu.my

**correspondance author*

To cite this article (APA): Zhong, T., Mat Saad, M. I., & Che Ahmad, C. N. (2022). Integrating technology-mediated learning in Biology education (Histology): A systematic literature review. *Journal of ICT in Education, 9*(1), 86-99. https://doi.org/10.37134/jictie.vol9.1.8.2022

To link to this article: https://doi.org/10.37134/jictie.vol9.1.8.2022

Abstract

Leveraging technology is an integral component of any 21st-century learning. Researchers and practitioners are still working on ways to improve student learning with the help of technology as a learning tool. Therefore, this study was carried out to study the effects of integrating technology-mediated learning in biology education using a systematic literature review (SLR) by employing the PRISMA technique. The analysis of selected literature found that the integration of technology-mediated learning has a significant positive impact on student's 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 by classifying the learning methods, approaches, and delivery methods.

Keywords: technology-mediated learning, mobile application, smartphone application, Histology, Biology education

INTRODUCTION

Information and communication technology (ICT) plays a critical role in teaching and learning. Nowadays, most 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.

ICT in education

Several studies in the literature explore the role of mobile ICT in the education system. Schrack (2014) reported that using ICTs in the classroom positively or neutrally influences 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 many teachers finding it challenging to integrate them (Végh et al., 2017).

Lim & Khine (2006) examined the teachers' reactions to challenges posed by 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 the teacher's person. The study revealed that teachers had difficulty 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 the challenges they encountered when teaching using ICT (Lim & Khine, 2006).

Meanwhile, Šorgo et al. (2010) investigated 70 biology teachers on why installing computers and laboratory equipment in classrooms was not as successful as expected. The biology teachers showed a positive response towards the willingness to use the internet and core Microsoft application in preparing classroom materials; and the willingness to use computer programs, presentations, and virtual laboratories, although some neglected such tools due to the insufficient skills and the size of the curriculum. The study revealed that teachers generally responded negatively and refused to use ICT, especially when it revolved around gamification and programming (Šorgo et al., 2010).

Another study in England explored the difficulties related to ICT-mediated learning. Webb (2002) mentioned that the knowledge transfer was not working correctly with the tools, even though ICT-supported school education may be improved by creating these tools. In general, this strategy is more difficult to apply in domains, especially in biology, where memorizing is a common pedagogical practice (Buckner & Kim, 2014).

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

ICT in Biology Education

The association and role of ICT in biology education are 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 (Watson, 2001). 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 (Végh et al., 2017).

In facilitating the education of biological cells and photosynthesis, using visual applications in class was deemed beneficial by 37 teachers who participated in the study (Mikropoulos et al., 2003). Computer-mediated stimulation (CMS) applications can also improve students' understanding of Cell Theory (Kiboss et al., 2004). Using computer animations, students can better understand abstract Molecular biology ideas and processes (Rotbain et al., 2008). 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 (Kagohara et al., 2013). In general, these technologies help improve biology study as a whole (Senthilkumar et al., 2014).

Based on the examples above, it is clear that ICT-mediated biology teaching was beneficial in various biology classrooms, whether it was a lecture, tutorial, or laboratory work. Biology teaching could be significantly more effective and fun for the 21st-century generation by upgrading ICT-mediated teaching methodologies and developing more customized 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 (Rinaldi et al., 2017). Researchers can either search for, innovate or invent applications that meet educational needs (Yang et al., 2019).

Because of the ever-changing technological landscape, basic science teaching methods must be innovative (Felszeghy et al., 2019). For some, elements of game-based are incorporated into the teaching method. Gamification enhances student learning by providing additional scaffolding (Felszeghy et al., 2019). The effects of the web-based Virtual Microscopy platform on students' academic performance are cumulative and synergistic (Lee et al., 2020).

Summary for ICT Research

Schacter (1999) summarise 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 (Schacter, 1999). Of late, many researchers reported a positive effect of using technology in general (Hamzat et al., 2017; Lee et al., 2020; Maske et al., 2018; Rinaldi et al., 2017; Rojas-Mancilla et al., 2019), 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 (Cuban & Jandrić, 2015; Mertala, 2020; Selwyn, 2010). Cuban & Jandrić (2015) reported no evidence that teachers and students would have benefitted from using computers in terms of student

participation in schools. Researchers must bridge the gap left by previous studies because there is no agreement on using technology in biology education, particularly in laboratory practical.

METHODOLOGY

This study is based on a systematic literature review of the last five years, from the year 2017 to the year 2021. The most recent material has been presented 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 were used to analyze the accumulated articles. The four steps in PRISMA are a) identification, b) screening, c) eligibility and d) inclusion. This technique was employed to guide the researcher to synthesize relevant article journals. Figure 1 outlines the steps taken in PRISMA, which are adapted and altered from Moher et al. (2009).

A. Identification

Literature had been extensively searched from the databases; ERIC, ProQuest and Google Scholar as they cover a massive and offer a wide scope of paid-for databases (Gusenbauer & Haddaway, 2020). It was deemed sufficient and comprehensive in literature (Gusenbauer, 2019). Keywords such as "technology-mediated learning", "mobile application", "smartphone application", "histology", and "biology education" were used for the identification purpose. The keywords used should connect to each other by using OR or AND or any suitable logical operator. Overall, 88 article journals were found at this stage.

B. Screening

The screening scope is confined to choosing only research-based articles in 1) learning using technology tools such as computers, laptops, smartphones, iPad, and tablets, 2) learning through software applications 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 were removed by title and abstract reading. After screening, 7 article journals did not adhere to the criteria of research and 39 repeated article journals were 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 discussed 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 made by following the checklist of the Strengthening the

Reporting of Observational Studies in Epidemiology (STROBE) (von Elm et al., 2014).

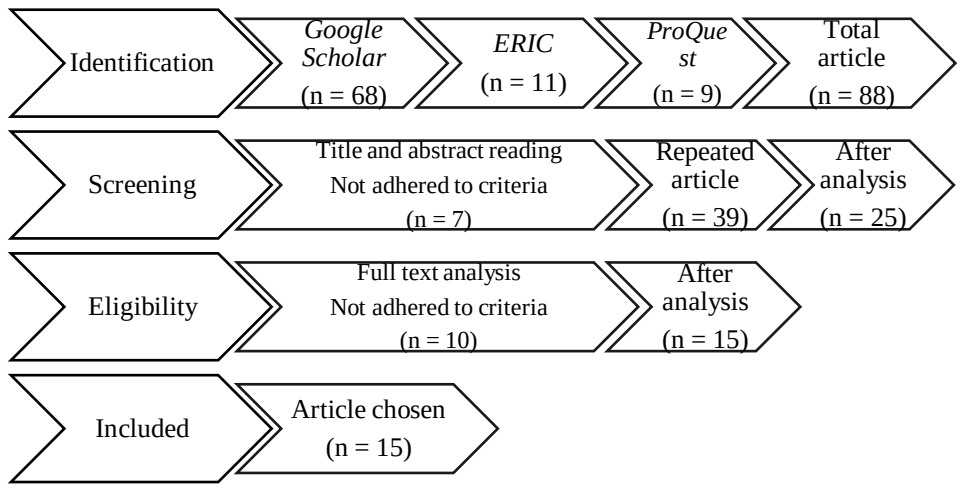

Figure 1: Adapted and altered process of article selection from Moher et al. (2009)

RESULTS OF THE STUDY

Summary of the Selected Article Journals

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

Table 1: Summary of the selected article journals

Study (year)	Sample Size	Research Design	Major Findings	Comments	Sources
Albino (2021)	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
Anggereini et al. (2018)	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 the 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

Study (year)	Sample Size	Research Design	Major Findings	Comments	Sources
Felszeghy et al. (2019)	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
Gould et al. (2019)	250 students divided into teams of 5-8 (20 teams selected for group interview)	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 a collaborative activity Technology as a useful addition to, though not a substitute for, a traditional microscope lab No control group	Journal of Biological Education
Hamzat et al. (2017)	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 significant difference between gender	Cypriot Journal of Educational Sciences
Jimena Medina et al. (2019)	122 undergrad students	Quantitative approach on primary data from students	NFC technology is a 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
Lee et al. (2020)	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	A combination of virtual and light microscopy remains the most preferred approach	Anatomical Sciences Education

Study (year)	Sample Size	Research Design	Major Findings	Comments	Sources
Maske et al. (2018)	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	The use of WhatsApp is an acceptable tool in teaching histology The use of WhatsApp is feasible as smartphones are readily available No control group	Journal of Education and Health Promotion
Necheva & Ingilizova (2018)	108 undergrad students	Quantitative oriented qualitative mixed approach (narrative) on primary data from students	More significant for part-time students to visualize via electronic means for histology	The E-learning approach is a preference by the part-time students in studying histology	Science and Technology
Che Ahmad et al. (2020)	100 students	Qualitative and quantitative mixed approach on primary data from students	Practical video (V-lab) accompanied by manual as an alternative to facilitate biology practical	Positive perception of using practical video and manual by students	Jurnal Pendidikan Sains & Matematik Malaysia
Rinaldi et al. (2017)	39 undergrad students	Quantitative approach on primary data from students	No overall difference between the treatment and control groups. Newest tools are not always better but rather act as a complement to the traditional instruction method	Using interactive cloud-based classroom response system (CRS) to identify misconceptions and provide feedback.	Anatomical Sciences Education
Rojas-Mancilla et al. (2019)	82 undergrad students	Quantitative approach on primary data from students	Support the use of gamification in the teaching of histology	The vast majority of students use gamification to study and positively perceive the learning method No control group	International Journal of Morphology
Subramaniam & Mohd Fadzil (2021)	6 students	Qualitative approach on primary data from students	Padlet has the 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
Végh et al. (2017)	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 the lesson more appealing and facilitating content delivery	Problems of Education in the 21st - Century

Study (year)	Sample Size	Research Design	Major Findings	Comments	Sources
Yang et al. (2019)	82 undergrad students	Quantitative approach on primary data from students	Smartphone application benefited students in histology	BAND application is not intended for education used The need to invent applications that fulfil the need for education	Anatomy & Biological Anthropology

Thematic Analysis of the Intended Outcomes from Incorporating Technology in Learning

Many researchers reported the positive effects of technology-mediated learning on academic achievement or learning experiences. Learning experience is classified into a) perception, b) knowledge enhancement, c) skill enhancement, and d) motivation. The classification is adapted, deduced and reclassified from (Mohd. Zainuddin et al., 2020). The results are summarised in Table 2.

Table 2: Thematic analysis of outcomes from the research

Study (year)	Academic Achievement	Learning Experience			
		Perception	Knowledge Enhancement	Skill Enhancement	Motivation
Albino (2021)		*			
Anggereini et al. (2018)					*
Felszeghy et al. (2019)	*	*	*	*	*
Gould et al. (2019)		*	*	*	*
Hamzat et al. (2017)	*				
Jimena Medina et al. (2019)	*	*	*		
Lee et al. (2020)	*	*	*		
Maske et al. (2018)	*	*	*	*	
Necheva & Ingilizova (2018)	*		*		
Che Ahmad et al. (2020)		*			
Rinaldi et al. (2017)	*	*	*		*
Rojas-Mancilla et al. (2019)	*	*	*		*
Subramaniam & Mohd Fadzil (2021)		*			
Végh et al. (2017)	*	*			*
Yang et al. (2019)		*			

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 technology integration. This study has identified six types of methods as input of learning: student-

created content, collaborative learning, active learning, blended learning, flipped learning, and components of technology-focused learning. This study discovered the following research that focused on technology-based learning approaches. 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 summarised in Table 3.

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

Study (year)	**Technology-mediated Learning Method**	**Technology-mediated Learning Approaches (d/e/m/u)**	**Technology-mediated Delivery Method**
Albino (2021)	Blended learning	m-learning d-learning	Lecture
Anggereini et al. (2018)	Collaborative learning	u-learning	Tutorial
Felszeghy et al. (2019)	Active learning Collaborative learning	e-learning	Lecture Lab
Gould et al. (2019)	Student-created content Active learning Collaborative learning	m-learning u-learning	Lab
Hamzat et al. (2017)	Components of technology-focused learning	e-learning	Lecture
Jimena Medina et al. (2019)	Active learning	m-learning	Lab
Lee et al. (2020)	Active learning Flipped learning	e-learning m-learning	Lab
Maske et al. (2018)	Student-created content Active learning Collaborative learning	m-learning	Lab
Necheva & Ingilizova (2018)	Blended learning Flipped learning	d-learning e-learning	Lecture Tutorial
Che Ahmad et al. (2020)	Blended learning Flipped learning	d-learning	Lab
Rinaldi et al. (2017)	Active learning Collaborative learning	e-learning	Lecture Lab
Rojas-Mancilla et al. (2019)	Active learning	d-learning m-learning	Lab
Subramaniam & Mohd Fadzil (2021)	Student-created content Collaborative learning	d-learning	Lecture
Végh et al. (2017)	Student-created content Collaborative learning Blended learning	d-learning e-learning	Lecture Tutorial
Yang et al. (2019)	Active learning Collaborative learning	m-learning	Lab

DISCUSSION

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 can detect the positive effect of technology-mediated learning in biology education, especially on the subject matter histology. The students can observe the positive effects on academic achievement or learning experience. Much research supported the integration of technology in learning on academic achievement and gave positive effects (Hamzat et al., 2017; Lee et al., 2020; Maske et al., 2018; Rinaldi et al., 2017; Rojas-Mancilla et al., 2019). Hamzat et al. (2017) depth in further and reported that females have more advantage in achieving practical assessment after integration of technology, but no significant 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 Mohd. Zainuddin et al. (2020) reported that Padlet, in intensifying engagement, enhances learning in students. Subramaniam & Mohd Fadzil (2021) suggested that positive perception of using Padlet will be retained, and negative perception has to be improved. It is further supported by the study carried out by Gould et al. (2019) on the interactive touch-screen monitor during histology practical. The integration had many positive impacts on students' perceptions. It transforms traditional plant anatomy lab into collaborative activity (Gould et al., 2019). Students indeed will learn collaborative skills as well as knowledge enhancement. The concept of technology-mediated collaborative learning should be given significant priority in the 21st-Century as this learning method is crucial in biology education. There is still a gap in the literature as limited research is being done in this field of study. Felszeghy et al. (2019) explored collaborative Kahoot-mediated histology learning, which gave a higher impact than individual Kahoot-mediated. Kahoot-mediated strengthened the students' positive attitudes toward histology. Besides that, motivations play an 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 groups for the studies done. It is observed in the research done by (Felszeghy et al., 2019; Gould et al., 2019; Jimena Medina et al., 2019; Maske et al., 2018; Rojas-Mancilla et al., 2019). Hence, there is a 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 using secondary data. Figure 2 shows the model of leveraging technology-mediated learning, adapted from (Islam Sarker et al., 2019).

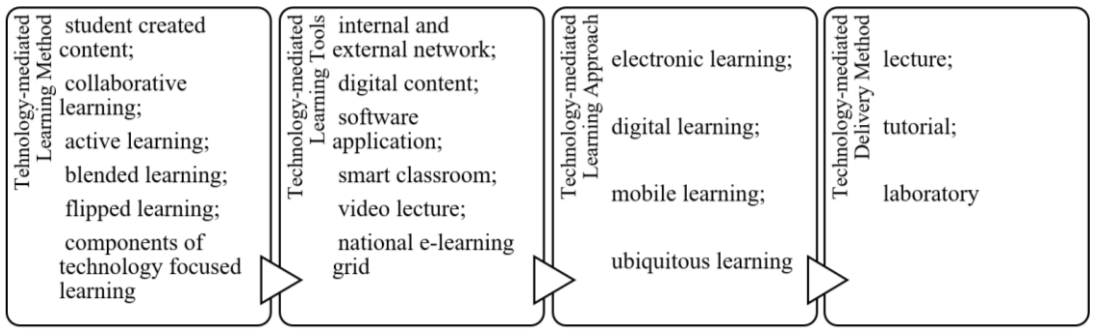

Figure 2: Model of leveraging technology-mediated learning adapted from Islam Sarker et al. (2019)

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 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 various 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 (Islam Sarker et al., 2019). E-learning and m-learning are revealed to be subcategories of d-learning (Kumar Basak et al., 2018). Some learning technologies, on the other hand, could be classified as both m-learning and e-learning. D-learning is a technology-mediated learning approach that allows learners to control their studying time, place, and path (Islam Sarker et al., 2019). It is, in fact, a combination of digital content, technology, and instruction.

Besides that, this study delves 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. The technology could serve as a link in this two-way communication channel. Sometimes, many schools use a flipped classroom, 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.

But due to rapid advancement of technology, for example, especially in virtual microscopy and slides in histology and plant anatomy, some of the laboratory's works has been substituted or complemented

with lecture or tutorial modes by leveraging technology in d-learning. Nevertheless, the ideal or optimal alternative in histology teaching would be an active learning approach (Michael, 2006) that melds microscope-based learning strategy with computer-based learning tools (Harris et al., 2001; Heidger et al., 2002; Pratt, 2009). It is a combination of virtual microscopy, either in lectures or tutorials, and light microscopy as laboratory works remains the most preferred approach (Gould et al., 2019; Lee et al., 2020).

CONCLUSION

In this study, a systematic literature review was carried out to explore the impact of integrating technology in biology education (histology). A general conclusion was made based on the analysis of the 15 previous research done. There is a significant positive impact on the students' academic achievement and learning experience 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 learning approaches associated with technology. They are a) electronic learning, b) mobile learning, c) digital learning, and d) ubiquitous learning. This study delves into implementing technology-mediated delivery modes, focusing on lecture, tutorial, and laboratory work. In order to maximize the full potential of technology-based learning methods, ICT should be integrated at all levels of curriculum development, learning processes, and delivery (Islam Sarker et al., 2019). Innovation and reform are required to ensure better education through ICT integration.

The research chosen for this systematic review primarily concerns histology undergraduate students as respondents. My proposed study primarily focuses on the Malaysian sixth-form biology students in histology laboratory work. My suggested topic is the effect of using the 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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