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M. Cleveland-Innes, Athabasca University

This next Canadian Journal of Learning and Technology issue is published on the heels of the well-attended ICDE (International Council for Open and Distance Education) conference. The Conference's overlapping topics and attendant researchers, well-known to this journal, remind us that our field is important, well-subscribed, growing, and changing. An excellent overview of this ICDE Conference and information about the state of education transformation in the current global context can be found here in recent blog posts by the well-known expert and author on the topic of education and technology, Dr. Tony Bates.

Learning and technology, the focus of research published by CJLT, is a microcosm in the much larger fields of open, distance, and digital education. Research spans all sectors: primary, secondary, post-secondary, higher education, and lifelong learning. Across issues and years, we seek to touch on the research, theory, and practice in these areas, particularly those where authors are in, or research topics are relevant to, Canada. Canadian researchers were well-represented at the recent ICDE conference, and a Canadian researcher received the conference's best paper award!

That ICDE conference's best paper described best practices when combining the community of inquiry (CoI) theoretical framework with blended learning. Covering that very topic, researchers Elena Chudaeva, Guilherm Loth, and Thuvaragah Somaskantha of George Brown College and Cynthia Blodgett-Griffin of Athabasca University are authors of article #1: ***Exploring Blended Learning Designs for Community College Courses Using Community of Inquiry Framework***. Using a case-based comparative approach, student groups in the same course from two different delivery formats, blended and in-person, identified their learning experience. Findings reveal differences in student presence scores across the formats. As might be predicted, those students engaged in a blended delivery format report more satisfaction with the flexibility in their course experience, but in-person students report more awareness of the standard three presences found in the CoI framework.

The pedagogical awareness and adjustment required by teachers using technology are significant. Moving into blended delivery and applying new pedagogical frameworks like the CoI requires time, effort, and professional development. The TPACK model, or Technological Pedagogical Content Knowledge support, was created to provide guidance about the use of technology in content and processes in teaching and learning. For the author of article #2, Suresh C. Joshi of Chandigarh University, India, understanding the usefulness of TPACK depends on teacher self-efficacy. In ***TPACK***

and Teachers' Self-Efficacy: A Systematic Review, Dr. Joshi identified, reviewed, and analyzed studies using TPACK. Results indicate that TPACK-based argumentation practices helped participants strengthen their perceptions toward the integration of technology for in-person delivery and that professional development contributes to improving teachers' TPACK self-efficacy. The article concludes with evidence-based implications for teacher preparation programs and other professional development activities.

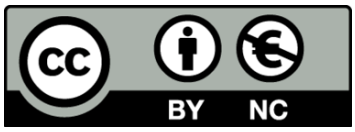
These development activities for new education technologies require clear description and evidence of the benefits and challenges. Artificial intelligence (AI) describes a different kind of technology: machines that are learning and adjusting based on inputs or responses. Software applications are better described as machines for learning rather than machines that learn. Comparing simpler machines to AI-driven systems is a pre-step to change. In article #3, ***A Comparison Between Virtual and Conventional Microscopes in Health Science Education***, University of Alberta researchers Nazlee Sharmin, Ava Chow, and Alice Dong compare virtual and real-light microscopes according to rates of usage and learner response. To verify this initial step, these authors "conducted a scoping review to investigate the comparative impact of conventional and virtual microscopes on different aspects of learning" (Abstract). Their results suggest that while learning through virtual microscopy is superior to traditional microscopes, traditional microscopes are still in everyday use. Common to our work in education change, the authors suggest where further research is needed. Before we conclude that virtual microscopes are the best pedagogical choice, more evidence and clear guidelines must be in place.

Evidence and guidelines are critical supports for any change in professional practice. The frequent narrative of education change also includes the call for increased access and inclusion for diverse marginalized populations. In article #4, University of Windsor researchers Sandra Raffoul and Lindsey Jaber carefully use self-regulated learning theory to assess the value of one type of software for students with disabilities. ***Text-to-Speech Software and Reading Comprehension: The Impact for Students with Learning Disabilities*** provides evidence that text-to-speech (TTS) software is beneficial. In this analysis, the use of TTS software supports increased outcomes such as reading comprehension and the pedagogical processes of motivation and self-efficacy. This software is most notably used in post-secondary education. However, these authors also note that access to this software first, and then training for appropriate use, is required. In this case, the required training is suggested for students, while article #3 the focus is on the need for educator training.

Our focus on software technology for learning continues in article #5 and into the Book Review. Both describe the main tenets of teaching music with technology, a subject matter that requires both content knowledge and psychomotor skills. ***Technology in Music Education*** by Adita Maharaj and Akini Gill**,** The University of Trinidad & Tobago, reports a test of music theory digital software and assessment of the learners' experience. The use of music instructional software correlates with 90% of the students successfully completing the required assignment. While learners reported being motivated by and comfortable with the software, more training was generally requested. This request is a common result of research testing new education technologies (see articles #3 and #4 in this issue).

The use of technology in music education is fully explored in the book ***A Framework for Teaching Music Online*** by Carol Johnson. In an evidence-based process, this author provides a clear and precise framework for teaching music online. The focus soundly rests on practical application and design for online teaching spaces which promotes specificity for an arts-based discipline, one that requires both psychomotor and knowledge development. Covering music theory, history, and composition, this framework offers authentic supports for anyone preparing to teach music online. This excellent book review is provided by Sandra Duggleby of the University of Calgary, Canada**.**

We hope you enjoy this issue.



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Exploring Blended Learning Designs for Community College Courses Using Community of Inquiry Framework

Exploration de la conception de cours hybrides pour les cours des collèges communautaires à l'aide du cadre de référence de la communauté d'enquête

Elena Chudaeva, *George Brown College*

Cynthia Blodgett, *Athabasca University*

Guilherm Loth, *Crandall University*

Thuvaragah Somaskantha, *Princess Margaret Cancer Centre*

Abstract

The goal of this single-phase and convergent mixed methods study was to compare the differences in the effectiveness of the Community of Inquiry (CoI) presences of a community college blended block instructional model with the in-person counterpart. Data were gathered from the Community of Inquiry Survey, Blackboard LMS reports, and course evaluation surveys. The results indicate that students had a better overall experience with the blended course. The blended block model provided flexibility while achieving course goals. Further, findings reveal differences in all three CoI presences between the two course formats with more student awareness of the presences in the in-person course.

Keywords: blended learning; community college; community of inquiry; teaching presence; social presence; cognitive presence; mixed methods

Résumé

L'objectif de cette étude utilisant des méthodes mixtes convergentes et en une seule phase était de comparer les différences dans l'efficacité des présences de la communauté d'enquête (CE) d'un modèle d'enseignement hybride en blocs d'un collège communautaire avec son homologue dans la modalité présentielle. Les données ont été recueillies à partir d'un sondage sur la communauté d'enquête, des rapports tirés du système de gestion de l'apprentissage Blackboard et des sondages d'évaluation des cours. Les résultats indiquent que les étudiants ont eu une meilleure expérience globale

avec le cours hybride. Le modèle de blocs hybrides offrait de la flexibilité tout en atteignant les objectifs du cours. De plus, les résultats révèlent des différences dans les trois présences de la CE entre les deux modalités de cours, les étudiants étant plus conscients des présences dans le cours en présentiel.

Mots-clés : apprentissage hybride ; collège communautaire ; communauté d'enquête; présence pédagogique ; présence sociale ; présence cognitive; méthodes mixtes

Introduction

Evidence suggests that blended learning provides more satisfaction and engagement (Taliaferro & Harger, 2022; Vaughan et al., 2013), results in similar examination scores to in-person courses (Jafar & Sitther, 2021; Shand et al., 2016), and positively impacts students' performance (Broadbent, 2017; Vo et al., 2017). Cleveland-Innes and Wilton (2018) identified several key benefits of blended learning, including increased learning skills, greater access to information, improved satisfaction and learning outcomes, and opportunities to learn with and teach others.

Brown (1992) argued that research should be undertaken in real classrooms with real students and teachers. Research has shifted to explore blended learning, outcomes, teacher factors, and Community of Inquiry (Yin & Yuan, 2022). While blended learning is appealing because it can encompass the best of both distance and in-person education (McKenna et al., 2020; Rovai & Jordan, 2004; Young, 2002), blended learning can potentially mix the least effective elements of both in-person and technology-mediated learning. The challenge is effectively combining both instructional designs with matching learners' characteristics and abilities (Drachsler & Kirschner, 2012; Garrison & Kanuka, 2004; Garrison & Vaughan, 2008).

This study systematically explored blended and in-person instructional models with the CoI teaching, cognitive, and social presences (Garrison, 2007) to support meaningful approaches to online teaching and learning (Vaughan et al., 2013). It adds to the body of mixed methods research in distance education, the least used approach, according to Bozkurt et al. (2015).

Literature Review

Defining Blended Learning

Blended learning is "a thoughtful integration of classroom face-to-face learning … with online experiences" (Garrison & Kanuka, 2004, p. 3). Bonk and Graham (2005) described blended learning systems as a combination of in-person and computer-mediated instruction for the same students studying the same content in the same course. Horn and Staker (2011) defined blended learning as "any time a student learns at least in part in a supervised brick-and-mortar location away from home and at least in part through online delivery with some element of student control over time, place, path, [and] pace" (p. 3).

Models of Blended Learning

Beyond definition, the design of blended learning instruction must be one that reflects the particular educational setting in order for it to be successful. Educational institutions have adopted various blended designs. O'Connell (2016) as cited in Cleveland-Innes & Wilton (2018) offered seven configurations:

- **blended face-to-face class:** This model is based in the classroom, while online activities supplement in-person classes.
- **blended online class:** The class is primarily conducted online, with some required in-person activities.
- **flipped classroom:** Students watch a short lecture video online and come into the classroom to complete activities such as group work.
- **rotation model:** Students in a course rotate between various modalities, one of which is online learning.
- **self-blend model:** This is a program-level model. Learners are enrolled in a school but take online courses in addition to traditional in-person courses.
- **blended MOOC:** This form of the flipped classroom uses synchronous, video-based online, meetings to supplement a massive open online course.
- **flexible-mode courses:** All instruction is offered in-person and online, and students choose how to take their course.

Cleveland-Innes and Wilton (2018) discussed several blended learning models for higher education:

- **blended presentation and interaction model:** This form has classroom engagement as its primary component, with support from online exercises.
- **blended block:** In this model, a sequence of blocks is used to incorporate both in-person learning and online study, usually considering both pedagogical goals and practical constraints.
- **fully online model:** While not usually considered blended, if it incorporates both synchronous learning (e.g., online tutorials) and asynchronous activities (e.g., discussion forums), it is sometimes referred to as blended.

Finally, in the HyFlex and Here or There (HOT) models, both on-site and remote students can attend learning activities in real-time (Raes et al., 2020; Zydney et al., 2019).

Effectiveness of Blended Learning

The effectiveness of blended learning, as identified in scholarly literature, includes student grades, satisfaction, flexibility, and retention. Studies found that final grades are similar in blended designs and in-person courses (Groen et al., 2020; Melton et al., 2009; Smith, 2013). Owston et al.

(2013) reported that students with higher grade point averages prefer online courses and performed equally well with content acquisition, regardless of the mode of delivery (Cavanaugh & Jacquemin, 2015; Smith, 2013; Tang & Byrne, 2007).

Students report higher satisfaction in blended courses (Larson & Sung, 2009; Taliaferro & Harger, 2022; Tseng & Walsh, 2015), which may be mediated by advanced course design (Patwardhan et al., 2020). Learner-content interaction is the most important predictor of satisfaction, considering that all three kinds of interaction (learner-learner, learner-instructor, and learner-content) positively affect learning (Kuo et al., 2009).

Higher perceptions of a learning community may result in more satisfaction with blended than in-person courses (Daigle & Stuvland, 2021). Students report that the opportunity to interact with other learners beyond the physical classroom is a positive feature of the blended approach (Cornelius et al., 2019).

In addition, students' personalities, age, and attitudes are vital factors in blended designs (Broadbent & Fuller-Tyszkiewicz, 2018; Kintu et al., 2017). Students prefer the flexibility of blended learning and faculty recognize the potential of blended learning to increase teacher-student interaction but acknowledge the need for more support in course redesign and training (Taylor et al., 2018). Student retention appears to be greater in blended as opposed to traditional courses (Groen et al., 2020).

Community of Inquiry

Developed by Garrison et al. (2000), the CoI has been one of the most extensively used frameworks to guide instruction and research in online education (Bozkurt et al., 2015; Castellanos-Reyes, 2020; Kim & Gurvitch, 2020; Martin et al., 2022; Stenbom, 2018). The CoI includes three components: teaching presence, social presence, and cognitive presence. Teaching presence is the design, facilitation, and direction of cognitive and social processes to realize personally meaningful and educationally worthwhile learning outcomes (Anderson et al., 2001). Social presence is "the ability of participants to identify with the community, communicate purposefully in a trusting environment, and develop inter-personal relationships by way of projecting their individual personalities" (Garrison, 2017, p. 25). Cognitive presence is the extent to which learners can construct and confirm meaning through sustained reflection and discourse (Garrison et al., 2001).

The CoI framework influences online teaching internationally. Arsenijevic et al. (2022) found differences in all three presences among six countries (Serbia, Croatia, Bosnia and Herzegovina, Slovenia, Romania, and Russia) during the COVID-19 pandemic, concluding that results depend on the educational context. Parrish et al. (2021) used the CoI to test a team-based approach to online learning with synchronous sessions in the USA. In Norway, Krzyszkowska and Mavrommati (2020) used the CoI model to recommend improving online learning designs to promote learning in the community. In the United Arab Emirates, Meda and ElSayary (2021) explored ways to establish all three presences during emergency remote teaching.

The CoI survey (Community of Inquiry, n.d.), validated by Swan et al. (2008), examines learning experiences and compares different learning contexts (Redstone et al., 2018; Stenbom, 2018).

Research Methods

This single-phase convergent mixed methods study aimed to compare the influence of the CoI in two community college courses: a blended block model and an in-person course. Convergent mixed methods design is a one-phase design where both qualitative and quantitative data are collected and analyzed within the same timeframe (Creswell & Creswell, 2017). Three research questions guided the study design and analysis:

1. What are students' perceptions of community of inquiry in in-person and blended courses?
2. What practices are associated with effective blended learning?
3. Was the chosen model of blended learning appropriate for college courses?

Qualitative and quantitative data were collected in parallel, analyzed separately, and merged. Quantitative data described students' perceptions of all three presences in the CoI framework. Open-ended data supplied different perspectives on course design features. Blackboard Learn 9.1 Analytics provided additional insights into learners' activity.

The instructor was also the primary investigator in the study; therefore, a student researcher collected data to avoid a perception of possible conflict of interest. The community college Research Ethics Board approved all measurement instruments used in the study.

Participants and Context

The study participants were a convenience sample of Canadian community college students enrolled in an elective physics course in Fall 2019 (Table 1).

Table 1

Characteristics of Study Participants

Total number of students	Gender		Program		
	Female	Male	Post-graduate certificate	Diploma	Advanced diploma
84	11	73	11	39	34

For most students, this was their first exposure to blended learning. The registration system did not mention the mode of delivery of the two courses, so students did not register for sections based on their preferred blended or in-person course delivery. The same instructor taught both the in-person and blended courses. Assessments were the same for both courses.

The blended block model (Cleveland-Innes & Wilton, 2018) was used to redesign the current in-person course, so the content was the same for both courses. The in-person sessions for the blended course were every other week, starting in week 1. During in-person sessions, students were introduced to a new topic and practiced new concepts individually and in small groups. During distance weeks,

students investigated online modules which included readings, videos, quizzes, simulations, self-assessment activities, and online asynchronous discussion forums on the Blackboard LMS.

Inclusive course design with accessible content and appropriate technology promotes widely known principles of good practice in education (Chickering & Gamson, 1987). Consultation with an instructional designer and Universal Design for Learning coach was integral to the whole study, considering the unique needs of community college learners.

Data Collection

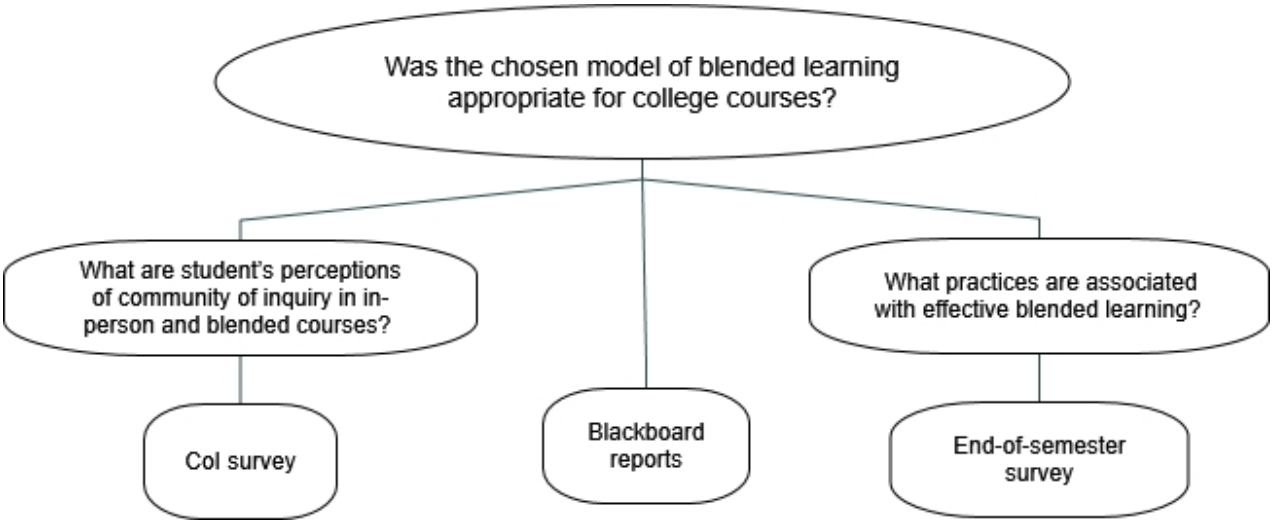
To answer research questions, three data collection processes were used (Figure 1):

- **CoI survey** (Arbaugh et al., 2008): Thirty-four questions using a Likert-type scale (1 = *strongly disagree* to 5 = *strongly agree*) to measure teaching, cognitive, and social presences.
- **End-of-semester survey**: Open-ended questions to evaluate design features and one question about overall learning experience on a Likert-type scale (1 = *poor* to 5 = *great*), as well as a question asking how much time the course required per week.
- **Blackboard reports analysis**: To provide additional insights on learners' activity and help evaluate course designs (le Roux & Nagel, 2018), we examined these three reports:
    - *All User Activity Inside Content Areas* displays a summary of activity inside content areas students use the most and the least.
    - *Overall Summary of User Activity* displays student activity for all course pages, including activity dates, times, and frequencies.
    - *Course-at-a-Glance* summarizes a comparison to other courses in the same department.

The research team administered the CoI survey and end-of-semester survey at the end of the semester. Twenty-eight anonymous students in the in-person class and 24 in the blended section completed all surveys, yielding a response rate of 62%. Blackboard reports were generated in the middle and end of the semester to gain additional insights into students' activity and behaviour online.

Figure 1

Research Questions and Data Collection Methods



Data Analysis

First, CoI survey data were organized in a spreadsheet for further analysis. Descriptive statistics calculated the mean and standard deviation for each CoI survey item. Also, a hypothesis test produced summative values for each CoI presence. Second, the end-of-semester survey open-ended data analysis included a word count (Leech & Onwuegbuzie, 2007), content analysis for common themes, and word cloud visualization (McNaught & Lam, 2010). The word count function in Microsoft Word calculated the total number of words in each response group. Even though word count can decontextualize a word to a point where it is not understandable (Leech & Onwuegbuzie, 2007), we believe that word frequency provides a good indication of meaningfulness because most of the responses were in the form of a short phrase.

A text visualization content analysis of the overall text (Bhowmick, 2006) compared the two sets of textual data. The iterative process of revisiting data to ensure accuracy strengthened authenticity and validity. Textual data for both courses were coded for common themes. The qualitative textual data were uploaded to NVivo (Version 12, Lumivero, 2022) to generate word clouds. Words from the same families (e.g., experiment and experiments) were considered one word. Tables with word frequencies generated by NVivo were analyzed to get the usage rate of each word. Usage rate is word frequency divided by the total number of words (Leech & Onwuegbuzie, 2007).

Results

Community of Inquiry Survey

Summarized respondents' ratings for the three presences were calculated (Table 2). Mean responses for the 34 items ranged from 3.39 (item 16, blended section) to 4.82 (item 6, in-person section); standard deviations were highest for item 22 (*SD* = 1.28; blended section) and lowest for item

6 (*SD* = 0.40; in-person section). Mean ratings across the three presences exceeded 4.0 (on a 5-point scale) and presented general agreement that CoI was evident in an in-person class. In the blended section, the mean exceeded 4.0 for teaching and cognitive presences but not for social presence. A two-tailed two-sample *t*-test with alpha set to 0.05 confirmed a significant difference between in-person and blended classes for social presence.

Table 2

Descriptive Statistics for CoI Presences

CoI presence	In-person [1]		Blended [2]		*p*-value
	M	*SD*	*M*	*SD*	
Teaching	4.57	0.46	4.53	0.49	0.765
Social	4.20	0.64	3.58	0.72	0.002
Cognitive	4.33	0.68	4.03	0.67	0.116

Note. [1] $N = 28$; [2] $N = 24$.

Survey results are shown in the Appendix. Examination provides a more detailed picture of learners' perspectives. Teaching presence was strongly felt via course design, organization, and facilitation. Even though all ratings were higher than 4.0, items related to developing a sense of community and providing feedback were among those with the lowest rating, indicating less agreement about the degree to which this behaviour was present. However, items related to feedback were rated higher in the blended section.

The survey results for social presence yielded some interesting differences between the two types of course delivery. Affective expression items rated above 4.0 for the in-person sections. However, only about half the students surveyed perceived web-based communication as a suitable medium for interaction. Open communication was perceived as successful when interacting with other students ($M > 4.0$) but not online, including in online discussions (in the blended class, the mean was about 3.9). Learners in both courses felt that they could "disagree with other participants" and "their point of view was acknowledged" ($M > 4.0$).

Data for cognitive presence items shows unanimous agreement that this presence was present in the in-person course ($M > 4.0$ for all items). Students in the blended section had mixed feelings: "problem posed" did not always create interest and motivation to explore further, but course activities "piqued curiosity." In the blended section, students felt strongly about the integration phase ($M > 4.0$ for all items); however, they were less sure that they had developed solutions applicable in practice ($M = 3.96$). Also, blended learners felt that "online discussions were valuable" in helping them "appreciate different perspectives" ($M = 4.04$).

End-of-Semester Survey

There were six questions in the survey, four of which were open ended. Data indicated that meaningful inclusion of technology has learning value for college students and helps increase engagement with course materials.

Question 1

When asked about overall learning experience (Table 3), answers revealed a higher rating for the blended section. Additionally, final grades were slightly different in both courses (Table 4).

Table 3

Means and Standard Deviations of the Overall Learning Experience

In-person		Blended	
M	*SD*	*M*	*SD*
4.43	1.00	4.50	0.70

Table 4

Means and Standard Deviations of Final Grades on a 100% Scale

In-person			Blended		
M	*SD*	Range	*M*	*SD*	Range
92.3	6.00	31.7	89.4	10.2	51.9

Next, findings for the four open-ended questions are presented. As shown in Table 5, the number of words in responses varied for each open-ended question. Tables 6, 7, 8, and 9 further analyze these eight sets of textual data. It is worth mentioning that in word clouds, the size of words can be used to compare ideas in one image only. Tables with usage rates are provided to assist with comparing two sets of data.

Table 5

Number of Words in Student Responses to Open-Ended Survey Questions

Question	Number of words	
	In-person	Blended
2	107	69
3	98	45
4	145	84
5	85	51

Question 2

When asked what activity they liked the most, students in both courses most often mentioned demonstrations and experiments (Table 6). However, in the in-person section, students mentioned these activities twice as often. Various in-class activities were also among their favourite activities. Also, students reported watching other people doing experiments as fun and educational.

Table 6

Frequency of Word Use in Response to the Question: Which Activity Did You Like the Most?

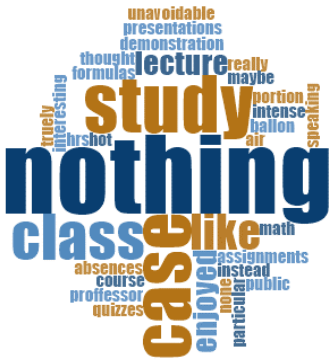
In-person		Blended	
Word clouds			
			
Usage rate of most popular words			
Word	Usage (%)	Word	Usage (%)
Demonstrations	16	Demonstrations	7
Experiment	7	Experiments	7
Class	7	Class	6
Project	5	Group	4
Case studies	2	Project	4

Question 3

Table 7 presents responses to question 3 which concerned the least liked class activity. Interestingly, the answer "nothing" appears in both sets but more frequently in the in-person section. In the blended class, online activities ("online" and "discussions") were the most frequent responses.

Table 7

Frequency of Word Use in Response to the Question: Which Activity Did You Like the Least?

In-person	Blended
Word clouds	
	

Usage rate of most popular words

Word	Usage (%)	Word	Usage (%)
Nothing	7	Online	13
Case	5	Discussions	11
Study	5	Material	5
Class	4	Case study	2
Enjoyed	2	Quizzes	2
Math	1	Nothing	2

Question 4

This question asked students what supported their learning of the course material (Table 8). In addition to in-class related activities (e.g., “class”, “demonstration”, and “lecture”), students in the in-person section mentioned “google” and “teacher” being supportive of their learning. Students in the blended class appreciated material designed for distance classes.

Table 8

Frequency of Word Use in Response to the Question: What Helped You Learn the Course Material?

In-person	Blended
Word clouds	
	

Usage rate of most popular words

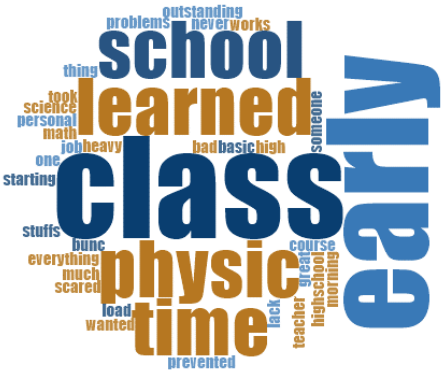
Word	Usage (%)	Word	Usage (%)
Class	4	Online	6
Case	2	Material	5
Demonstrations	2	Class	4
Lectures	2	Reading	4
Studies	2	Demonstration	2
Experiments	1	Teacher	2

Question 5

College students are diverse in background, prior knowledge, and personal and job situations. In addition, due to the nature of general education courses, students have different course loads. As shown in Table 9, answers to a question about what prevented the participants from learning varied from the timetable and work-related issues to course design features. It is worth noting that students in the in-person class mentioned “personal problems”, and “motivation” was mentioned in the blended section.

Table 9

Frequency of Word Use in Response to the Question: What Prevented You from Learning?

In-person	Blended
Word clouds	
	

Usage rate of most popular words

Word	Usage (%)	Word	Usage (%)
Early	4	Online	4
Class	4	Read	4
School	2	Lack	2
Time	2	Lazy	2
Personal problems	2	Motivation	2

Note. The most frequent answer in both sections, "nothing" (12% of the total number of words) was removed from the analysis.

In an analysis of survey data concerning the instructor, it was found that students appreciated material posted on Blackboard, in-class handouts, in-class activities, and good facilitation of classes (Table 10).

Table 10

Instructional Activities That Supported Learning

Instructional activity	Percentage of students mentioning the activity	
	In-person	Blended
In-person sessions	61	30
Materials on Blackboard	25	73

Instructional activity	Percentage of students mentioning the activity	
	In-person	Blended
Students' demonstrations	64	33
Instructor's demonstrations	29	42

Question 6

The survey also asked students how much time they spent on online activities each week. Considering that the standard weekly class is three hours, students in the blended course spent less time studying during distance weeks than students in the in-person class. Also, a couple of students in the in-person class suggested reducing class time to two hours. Lastly, according to self-reported time, students spent less than 3 hours per week on activities on Blackboard (Table 11).

Table 11

Number of Hours Spent Each Week on Online Activities

In-person		Blended	
M	*SD*	*M*	*SD*
0.9	0.9	1.3	0.5

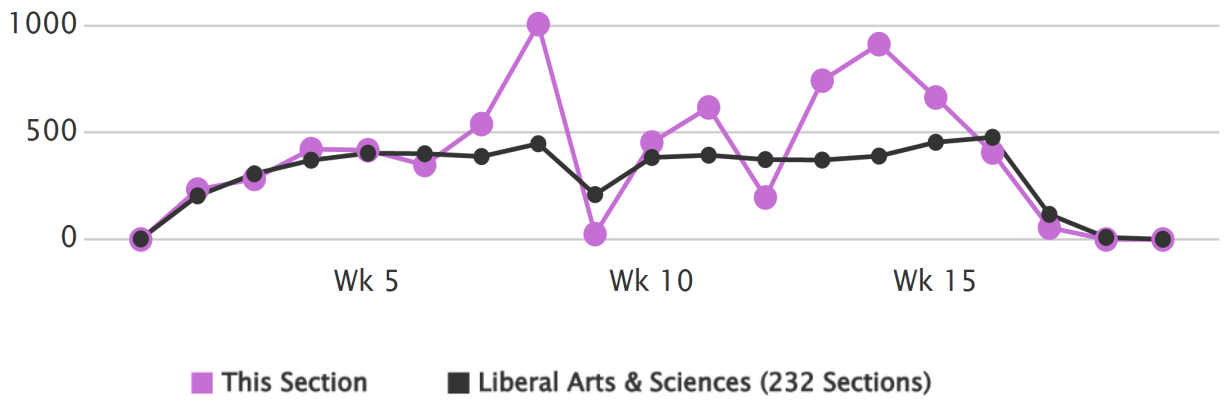
Blackboard Reports

Course-at-a-Glance

Reports reveal that the blended course had higher access, interaction, and minutes than the in-person course and department averages (Figures 2 and 3). Students in the blended class tended to access Blackboard regularly, whereas in the in-person class, access was mostly during assessment periods (weeks 9 and 14).

Figure 2

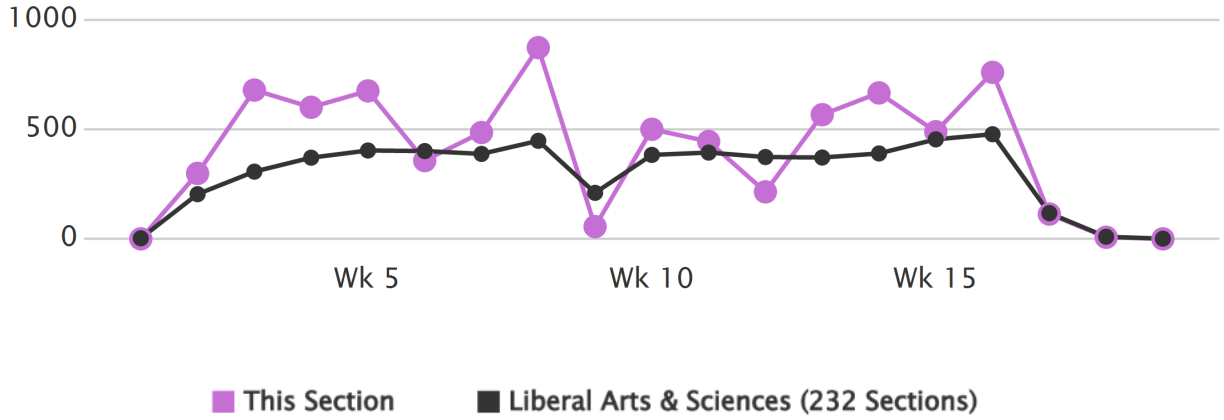
Minutes Spent on Blackboard Weekly: In-Person Course Students



Note. Wk = week.

Figure 3

Minutes Spent on Blackboard Weekly: Blended Course Students



Note: Wk = week.

All User Activity Reports

Data confirm that students in the blended course accessed the content area more often and consistently. Students visited the area with assessment tasks most often. In the blended section, the number of hits was twice the number for the in-person section. Unexpectedly, user activity inside content areas decreased in the second half of the course (Table 12).

Table 12

Number of Hits Inside Content Area Per Course Period

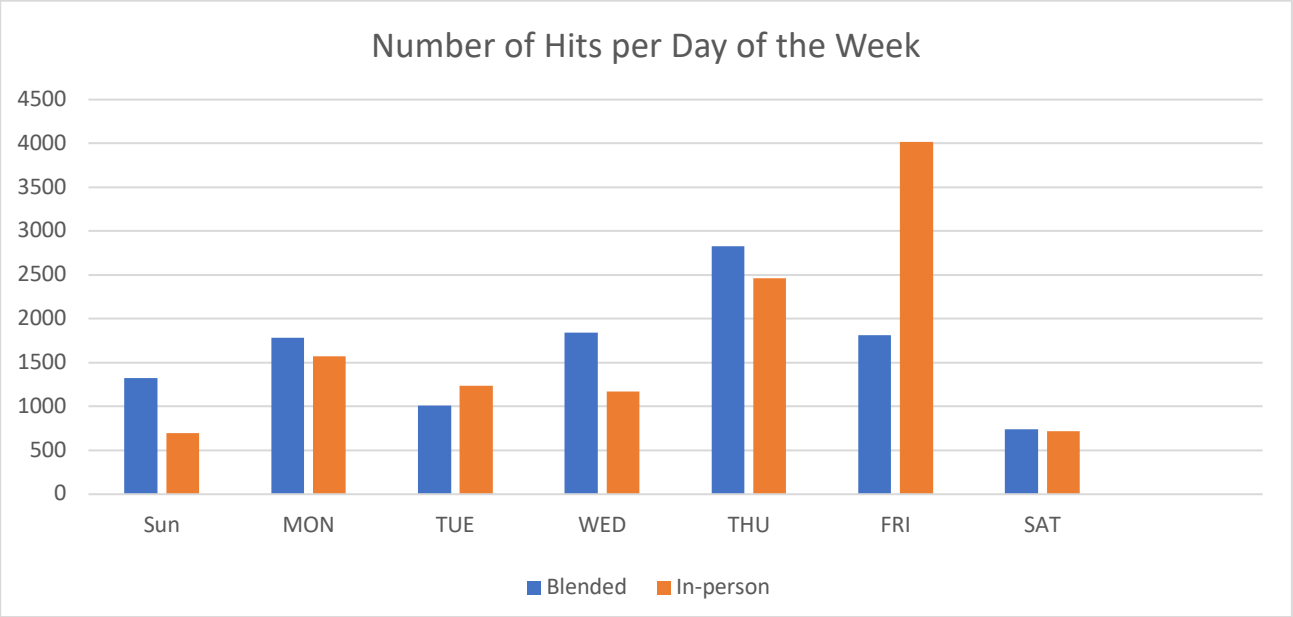
Course period	In-person	Blended
Weeks 1 to 7	1,285	1,334
Weeks 8 to 15	981	889

Overall Summary of User Activity Reports

Students accessed the course most often on the day of the class: of all accesses per week, 46% for the in-person section were on Friday and 38% for the blended class were on Thursday. However, students in the blended class demonstrated more consistent activity throughout the week (Figure 4).

Figure 4

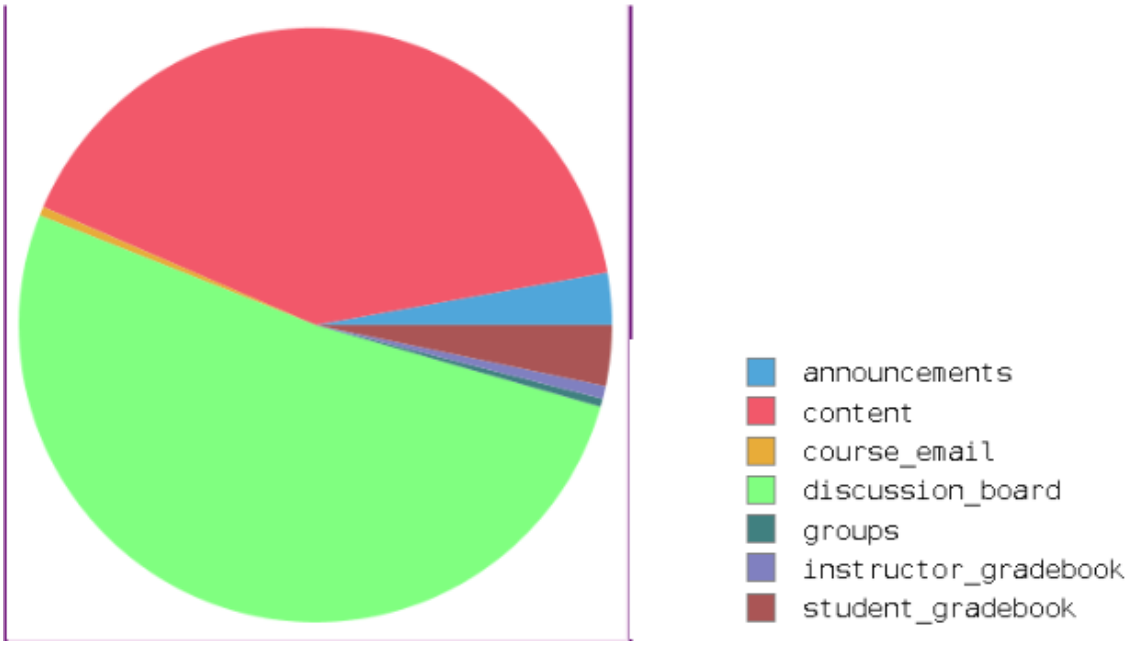
Daily Number of Hits on Blackboard: In-Person vs. Blended



Blackboard reports also provided insight into assessing course design based on students' online behaviour. Figure 5 illustrates that students in the blended course accessed online discussions more often than the content area. In the in-person section of the course, as might be expected, students most often accessed the course's content area (posted learning materials); there were no discussion forums.

Figure 5

Frequency and Type of Content Accessed by Students in the Blended Course



Discussion

Analysis of the CoI survey responses reveals that teaching presence had the highest rating for both courses. Teaching presence is key to establishing and sustaining a community of inquiry (Cornelius et al., 2019; Garrison et al., 2010; Redstone et al., 2018). The most favourite activity in both courses, demonstrations by the instructor and students, was a valuable contributor to the high rating of teaching presence. Access to course materials on demand has been helpful, especially around test times. Planning and organizing materials before and during the course support a strong teaching presence (Courduff et al., 2021; le Roux & Nagel, 2018).

Interestingly, students in the blended course placed greater value on the effectiveness of the instructor's feedback. Online discussions allowed students to contribute meaningfully to the community of learners and instructors to respond promptly to correct misconceptions and direct further learning more effectively based on individual needs. However, facilitation of the overall learning process was rated higher in the in-person class. This may be showing the importance of teacher support in blended courses to keep students motivated to study online due to a wide range of self-regulated learning profiles (Broadbent & Fuller-Tyszkiewisz, 2018; Fryer & Bovee, 2018).

Social presence was significantly lower in the blended course than in the in-person course. A lower rating for social presence is consistent with other studies (Cornelius et al., 2019; Honig & Salmon, 2021; Lacaste et al., 2022; Stewart et al., 2021). Even though students in the blended section visited online discussions more often than the course materials and were comfortable interacting with other participants, they did not feel that they knew other course participants well. Unexpectedly, a

sense of belonging was rated higher in the blended course. One possible explanation could be that online discussions positively affect identifying with the class community by allowing every student to contribute. A higher perception of social presence in the in-person class was anticipated because students were more familiar with in-person experiences and were first-time learners in a blended environment. Communication effectiveness in online environments is still an important area of inquiry (Kim & Gurvitch, 2020). Group cohesion was rated similarly for both courses. This shows that blended learning allows to build relationships due to the in-person component and online discussions even though students meet less often than in the in-person course. Since social presence has a connection to teaching and learning elements (Garrison et al., 2010), paying particular attention to connections between in-person and online components of blended learning may support the development of social presence.

Course design considered Meyer's (2003) and Vaughan and Garrison's (2005) suggestion that the triggering event and exploration phases were preferably done in person. Results reveal the difference between all cognitive presence categories and integration and resolution phases were more active in the in-person course whereas, in the blended course, only the integration phase was most active. Such a difference in the triggering event phase between the two classes was unexpected. The blended course was designed to introduce new concepts in the in-person weeks and then allow students to master them during online weeks. The explanation could be that in-person sessions in the blended course resulted in more cognitive load and faster exploration of new concepts, while distance weeks required more self-regulation. Also, students had mixed perceptions about activities during distance weeks in the blended course; some felt online materials and online discussions supported learning, and at the same time, online discussions were among the least favourite activities. Lower ratings for the cognitive presence in the blended course may be connected to the lower ratings for social presence, confirming that cognitive presence and social presence reinforce each other and have a two-way dynamic (Redstone et al., 2018).

Learner activity on Blackboard is an essential source of information about learning and course interactions that can shed light on course design features. In this case, reduced activity in the second half of the semester may be due to course design; less posted content and more assessment activities compared to the first half of the course.

Final grades demonstrate a wider range for the blended section. Adaptation to blended learning environments may be a factor as they are known to be required for students (Cleveland-Innes & Garrison, 2010). According to Blackboard reports, blended designs foster more significant interaction with course material and with peers, and the development of digital literacy. Consistent with Bates' (2019) idea about teaching in a digital age and skills students should acquire, we can conclude that blended learning provides an opportunity to develop valuable digital, collaboration, and communication skills. Promoting self-regulated strategies in blended college courses would help students gain new skills required to be effective online learners (Wandler & Imbriale, 2017).

Limitations and Further Research

The convenience sample used for data collection and relatively small classes could be considered limitations. Future studies can overcome these limitations by exploring the benefits and challenges of blended learning using another sampling method. Also, replication of this study with another instructor teaching both in-person and blended courses in a different educational setting, but using the same model, may provide additional insights. Since there are many ways to create blended learning environments, this study provides some insights into the possible design of general education STEM courses.

Further, policymakers and practitioners need research-based information about the conditions and practices under which online and blended learning are effective. Additional research is required to explore the CoI framework as a tool for creating effective blended environments for community college learners with different motivation levels and ways of adapting to online/blended learning environments.

Conclusion

This study explored the blended block model for community college courses. Results indicate that this model was as effective as an in-person course in meeting learning outcomes with the benefits of flexibility for students. However, the findings should be generalized with caution due to variables such as a specific model for blended learning, students' characteristics, the nature of instructional goals, and learning resources. One of the significant contributions of this research is the examination of the CoI framework in blended courses in a community college setting. In addition, we should not forget about skills that students need to develop for success in a digital age and in the VUCA (volatile, uncertain, complex, and ambiguous) world in which we live. Findings support that well-designed blended learning is an excellent opportunity to practice these skills in a safe environment for community college students. All in all, blended courses have the potential to create enhanced opportunities for teacher-student interaction, added flexibility in the teaching and learning environment, and opportunities for continuous improvement (Vaughan, 2007).

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Appendix

Community of Inquiry Presences Survey Results

Indicator	In-person							Blended						
	M	*SD*	%					*M*	*SD*	%				
			1	2	3	4	5			1	2	3	4	5
TEACHING PRESENCE														
Design & Organization														
1. The instructor clearly communicated important course topics.	4.61	0.96	0	0	11	21	70	4.58	0.72	0	4	0	29	67
2. The instructor clearly communicated important course goals.	4.61	0.57	0	0	4	32	64	4.54	0.59	0	0	4	38	58
3. The instructor provided clear instructions on how to participate in course learning activities.	4.64	0.68	0	4	0	25	71	4.71	0.55	0	0	4	21	75
4. The instructor clearly communicated important due dates/time frames for learning activities.	4.79	0.42	0	0	0	21	79	4.71	0.55	0	0	4	21	75
Facilitation														
5. The instructor was helpful in identifying areas of agreement and disagreement on course topics that helped me to learn.	4.68	0.55	0	0	0	25	71	4.62	0.78	0	0	17	25	58
6. The instructor was helpful in guiding the class towards understanding course topics in a way that helped me clarify my thinking.	4.82	0.40	0	0	0	18 [a]	81 [a]	4.50	0.66	0	0	8	33	58
7. The instructor helped to keep course participants engaged and participating in productive dialogue.	4.57	0.74	0	4	4	25	68	4.54	0.59	0	0	4	38	58
8. The instructor helped keep the course participants on task in a way that helped me to learn.	4.61	0.63	0	0	7	25	68	4.5	0.59	0	0	4	42	54
9. The instructor encouraged course participants to explore new concepts in this course.	4.64	0.56	0	0	4	29	68	4.63	0.58	0	0	4	29	67
10. Instructor actions reinforced the development of a sense of community among course participants.	4.32	0.82	0	4	11	36	50	4.29	0.81	0	0	21	29	50

Indicator	In-person							Blended						
	M	*SD*	%					*M*	*SD*	%				
			1	2	3	4	5			1	2	3	4	5
Direct Instruction														
11. The instructor helped to focus discussion on relevant issues in a way that helped me to learn.	4.57	0.57	0	0	4	36	61	4.38	0.70	0	0	13	38	50
12. The instructor provided feedback that helped me understand my strengths and weaknesses relative to the course's goals and objectives.	4.18	0.82	0	4	14	43	32	4.42	0.78	0	0	17	25	58
13. The instructor provided feedback in a timely fashion.	4.46	0.64	0	0	7	39	54	4.63	0.58	0	0	4	29	67
SOCIAL PRESENCE														
Affective Expression														
14. Getting to know other course participants gave me a sense of belonging in the course.	4.39	0.89	0	4	14	21	61	4.58	1.00	4	4	29	42	21
15. I was able to form distinct impressions of some course participants.	4.14	0.93	0	4	25	25	46	3.79	0.98	4	0	33	38	25
16. Online or web-based communication is an excellent medium for social interaction.	4.07	1.01	0	11	14	32	43	3.39	1.27	9	17	22	30 [b]	22 [b]
Open Communication														
17. I felt comfortable conversing through the online medium.								3.96	0.95	4	0	21	46	29
18. I felt comfortable participating in the course discussions.	4.25	0.65	0	0	11	54	36	4.12	1.09	4	4	13	29	50
19. I felt comfortable interacting with other course participants.	4.39	0.63	0	0	7	46	46	4.33	0.70	0	0	13	42	46
Group Cohesion														
20. I felt comfortable disagreeing with other course participants while still maintaining a sense of trust.	4.18	0.77	0	0	21	39	39	4.21	0.59	0	0	9	63	29
21. I felt that my point of view was acknowledged by other course participants.	4.36	0.68	0	0	11	43	46	4.29	0.69	0	0	13	46	42

Indicator	In-person							Blended						
	M	*SD*	%					*M*	*SD*	%				
			1	2	3	4	5			1	2	3	4	5
22. Online discussions help me to develop a sense of collaboration.								3.92	1.28	8	4	21	21	46
COGNITIVE PRESENCE														
Triggering Event														
23. Problems posed increased my interest in course issues.	4.29	0.69	0	0	18	36	46	3.75	1.07	4	4	21	42	25
24. Course activities piqued my curiosity.	4.18	0.86	0	7	7	46	39	4.12	0.96	0	8	13	33	46
25. I felt motivated to explore content related questions.	4.25	0.93	0	7	11	32	50	4.00	0.59	0	4	13	58	25
Exploration														
26. I utilized a variety of information sources to explore problems posed in this course.	4.36	1.03	4	4	7	25	61	3.83	1.01	4	4	21	46	25
27. Brainstorming and finding relevant information helped me resolve content related questions.	4.36	0.91	0	7	7	29	57	4.13	0.80	0	4	13	50	33
28. Online discussions were valuable in helping me appreciate different perspectives.								4.04	1.00	4	0	21	38	38
Integration														
29. Combining new information helped me answer questions raised in course activities.	4.61	0.74	0	4	4	36	57	4.17	0.82	0	4	13	46	38
30. Learning activities helped me construct explanations/solutions.	4.23	0.79	0	4	7	32	57	4.29	0.69	0	0	13	46	42
31. Reflection on course content and discussions helped me understand fundamental concepts in this class.	4.21	0.96	0	7	14	29	50	4.17	1.00	4	0	17	33	46
Resolution														
32. I can describe ways to test and apply the knowledge created in this course.	4.54	0.64	0	0	7	32	61	4.13	0.74	0	0	21	46	33
33. I have developed solutions to course problems that can be applied in practice.	4.36	0.87	0	7	4	36	54	3.96	0.86	0	4	25	42	29

Indicator	In-person							Blended						
	M	*SD*	%					*M*	*SD*	%				
			1	2	3	4	5			1	2	3	4	5
34. I can apply the knowledge created in this course to my work or other non-class related activities.	4.39	0.92	0	7	7	25	61	4.13	0.80	0	0	25	38	38

Note. Empty cells indicate response was not applicable. 1 = strongly disagree; 2 = disagree; 3 = neutral; 4 = agree; 5 = strongly agree.

[a] $N = 27$; [b] $N = 23$.

From *Community of Inquiry Survey*, by B. Arbaugh, M. Cleveland-Innes, S. Diaz, D. R. Garrison, P. Ice, J. Richardson, P. Shea, and K. Swan, n.d., The Community of Inquiry (https://coi.athabascau.ca/coi-model/coi-survey/). CC BY-SA.

Authors

Elena Chudaeva is associate professor of physics and mathematics in the School of Liberal Arts and Sciences at George Brown College in Ontario, Canada. Current research interests include educational technology for active learning in STEM courses, online learning, and Universal Design for Learning. *Email*: echudaev@georgebrown.ca

Dr. Cynthia Blodgett is an international distance educator and course designer with over 30 years' experience. For the past 20 years, she has taught graduate research and thesis development and supervised thesis and dissertation students at Athabasca University. Her research interests include disability studies, trauma-informed teaching, and student self-care. *Email*: cynthiab@athabascau.ca

Guilherme Loth, Master of Management Sciences, is the Senior Director of Remote Learning at Crandall University in Moncton, New Brunswick, Canada. His primary work and study are on innovation in online learning. *Email*: guilhermeloth@gmail.com

Thuvaragah Somaskantha, BMT-IEC Program Data Coordinator at Princess Margaret Cancer Centre in Toronto, Ontario, Canada. She holds a BSc from the University of Waterloo, Canada, diploma in Health Information Management from George Brown College, Canada, and a CHIM designation in good standing with the Canadian Health Information Management Association. *Email*: thuvaragah.somaskantha@georgebrown.ca

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TPACK and Teachers' Self-Efficacy: A Systematic Review

TPACK et l'auto-efficacité des enseignants: une revue systématique

Suresh C. Joshi, *Chandigarh University, India*

Abstract

Technological Pedagogical Content Knowledge (TPACK) studies have surged over the past few years, however, there is a lack of studies that have comprehensively reviewed and synthesized data on teachers' TPACK self-efficacy. The present review aimed to provide data on research methods, study samples, subject domains, and evaluation approaches used in the TPACK studies to date. The review also aimed to analyze teachers' TPACK self-efficacy, self-efficacy beliefs, computer self-efficacy, and technology support concerning professional development. Five best bets (most searched databases) were selected on the Electronic Business Source Complete (EBSCO) host platform. An abstract level screening was conducted for 136 peer-reviewed articles, and 75 articles were selected for the detailed screening. The analyses were focused on year-wide appearance of TPACK studies, research methods, study samples, subject domains, and evaluation approaches used. The growth and development of TPACK self-efficacy was examined using the narrative approach. Results indicated that professional development interventions were effective in improving teachers' TPACK self-efficacy. Also, TPACK-based argumentation practices helped participants strengthen their perceptions toward the integration of technology in classrooms. The implications of the findings for teacher preparation programs and other professional development activities were presented.

Keywords: TPACK; self-efficacy; instructional technology; professional development

Résumé

Les études sur les connaissances du contenu pédagogique technologique (TPACK, par ses sigles en anglais) ont augmenté au cours des dernières années, cependant, il y a un manque d'études qui ont examiné et synthétisé de manière exhaustive des données sur l'auto-efficacité TPACK des enseignants. La présente revue de literature visait à fournir des données sur les méthodes de recherche, les échantillons de l'étude, les domaines d'études et les approches d'évaluation utilisées dans les études TPACK à ce jour. La revue visait également à analyser l'auto-efficacité TPACK des enseignants, les croyances d'auto-efficacité, l'auto-efficacité en matière informatique et le soutien technologique

concernant le développement professionnel. Cinq meilleurs paris (les bases de données les plus recherchées) ont été sélectionnés sur la plateforme hôte d'Electronic Business Source Complete (EBSCO). Une sélection à partir du résumé a été effectué pour 136 articles évalués par des pairs, et 75 articles ont été sélectionnés pour un examen détaillé. Les analyses se sont concentrées sur l'apparition, à travers l'année, des études sur le TPACK, des méthodes de recherche, des échantillons d'étude, des domaines d'études et des approches d'évaluation utilisées. La croissance et le développement de l'auto-efficacité TPACK ont été examinés en utilisant une approche narrative. Les résultats ont indiqué que les interventions de perfectionnement professionnel ont été efficaces pour améliorer l'auto-efficacité TPACK des enseignants. En outre, les pratiques d'argumentation basées sur le TPACK ont aidé les participants à renforcer leurs perceptions vers l'intégration de la technologie dans les salles de classe. Les implications des résultats pour les programmes de perfectionnement des enseignants et d'autres activités de perfectionnement professionnel ont été présentées.

Mots-clés : TPACK ; auto-efficacité ; technologie d'enseignement ; perfectionnement professionnel

Background and Introduction

Technology can play a crucial role in transforming teaching-learning pedagogy. New classroom technologies such as tablet computers, interactive whiteboards (IWBs), social media, online simulations, and smartphones allow teachers to radically transform the ways they can help their students to learn new content and skills (Cennamo et al., 2010; DeSantis, 2013). More technologies are becoming readily available and these constantly evolving technologies are now part of the everyday life experiences of the digital natives (Ito et al., 2010). These technological advancements perhaps helped in flipping the role of the teacher from the curriculum designer to the content delivery facilitator who chooses an appropriate technology along with the pedagogy to do that (Kereluik et al., 2010). Teachers dealing with the learners of this century need to be skilled in integrating technology with the classroom activities as the appropriate use of technology has proven to enhance learning environments. Consequently, this brings changes in instructional strategies, classroom management, and tech-based classroom interventions (Kazu & Erten, 2014). Studies indicated that technological literacy and technological competence were the vital components for the integration of technology into teaching. Such skills help instructors have control over the instructional design and development in this age of technology (Kereluik et al., 2010).

The Technological Pedagogical Content Knowledge (TPACK) framework was one of the frequently used frameworks for understanding the integration of technology with pedagogy and content, which was built upon Shulmans' (1986) analysis of pedagogical content knowledge. As per Shulman, pedagogy and content were inseparable components of learning. Shulman further described that the efficacy of integrating pedagogical skills with the content was of considerable importance in education (Shulman, 1987). The TPACK framework integrated the knowledge of technology with the content and the pedagogy (Harris et al., 2009; Koehler et al., 2007; Koehler & Mishra, 2005; Koehler & Mishra, 2008; Mishra & Koehler, 2006; Schmidt et al., 2009). TPACK helped conceptualize the complex relationships between content and the integration of technology with the content, and helped

teachers improve classroom effectiveness (Baka et al., 2020; Kilic et al., 2019; Schmid et al., 2021). Such integration of technology into learning strategies was used to improve classroom practices in the digital century (Rocha et al., 2011).

Evaluation of TPACK

TPACK has evolved as one of the powerful frameworks addressing the successful integration of technology into classroom instruction (Koehler & Mishra, 2008). TPACK was evaluated in numerous studies using diverse samples and approaches to explore the framework further (Koehler et al., 2014). TPACK's widespread impact was criticized for inaccurate and insufficient definitions of knowledge domains as well as the integration of the technology domain into the model (Anderson et al., 2001; Cox & Graham, 2009; Graham, 2011). Nevertheless, TPACK has been applied to various tech-based academic settings, which, consequently, has helped TPACK grow as a useful framework for analyzing self-efficacy (Angeli & Valanides, 2009; Baran et al., 2011; Mishra & Koehler, 2006; Polly, 2011). Despite the ample attention that TPACK has received, it was rarely applied in studies incorporating ongoing activities in order to strengthen performance in teaching and professional development interventions (Willermark, 2017).

Small- and large-scale reviews, incorporating distinct scopes and foci, have been published in the past (Chai et al., 2013; Voogt et al., 2013; Wu, 2013). The literature review conducted by Willermark in 2017 focused on how TPACK was categorized in research. According to Willermark (2017), the studies published between 2011 and 2016 followed two major approaches: self-report and performance on the activity. Self-report and performance in teaching activities were further sub-categorized into general and specific, experienced and planning - implementing and evaluating teaching activities, respectively (Willermark, 2017). Other reviews focused on empirical studies incorporating survey analysis, content analysis, facilitation activities, and TPACK-based argumentation practices comprising experimental training.

Study Rationale, Purpose, and Research Questions

Previous studies have indicated that TPACK-savvy teacher-taskforce can fulfill learners' classroom expectations better as the students from the digital age feel confident about their learning with tech-savvy instructors (Alotumi, 2020; Buss et al., 2018; Ca et al., 2019). Since its inception, TPACK, as a framework, was evaluated in different educational settings on various platforms. However, a study presenting data about research methods, study samples, subject domains, and evaluation approaches used in all the TPACK studies to date was not available. Further, a study analyzing teachers' TPACK self-efficacies, self-efficacy beliefs, computer self-efficacy, technology support, and associated derivative variables concerning professional development interventions has been missing. Therefore, it was proposed to analyze research methods, study samples, subject domains, and evaluation approaches used in the TPACK studies to date. It was also proposed to analyze teachers' TPACK self-efficacies, self-efficacy beliefs, computer self-efficacy, technology support, and associated derivative variables concerning professional development interventions.

The specific aim of the present study was to answer the following research questions:

RQ1: To what extent has the TPACK Framework expanded in terms of research methods, study samples, subject domains, and evaluation approaches?

RQ2: What is the impact of tech-based professional development interventions on teachers' TPACK self-efficacy?

Significance to the Field

The outcomes of this study could serve as a guiding document for the researchers and policymakers for conducting future research concerning TPACK, technology self-efficacy, and tech-based pedagogical innovations both in online and in-person modes of instructional design and delivery. The outcomes could also help researchers incorporate more empirical settings and methods into future studies, which could provide a new perspective on the integration of TPACK into teacher professional development. In addition, the outcomes could help provide insight into the relationship between the knowledge domains within the framework, which could benefit tech-based professional development interventions, both for pre-service and in-service teachers.

Validating the outcomes of previous TPACK studies may be one of the key interests of future researchers, especially at K-12 and K-16 levels. The outcomes of this study could help researchers compare and critically analyze research settings, study samples, research methods, and evaluation approaches used in previous studies. Such analyses can be used for studies concerning the impact of developmental processes on teachers' TPACK-21CL design confidence, argumentation-based TPACK studies, and design-based scaffolding.

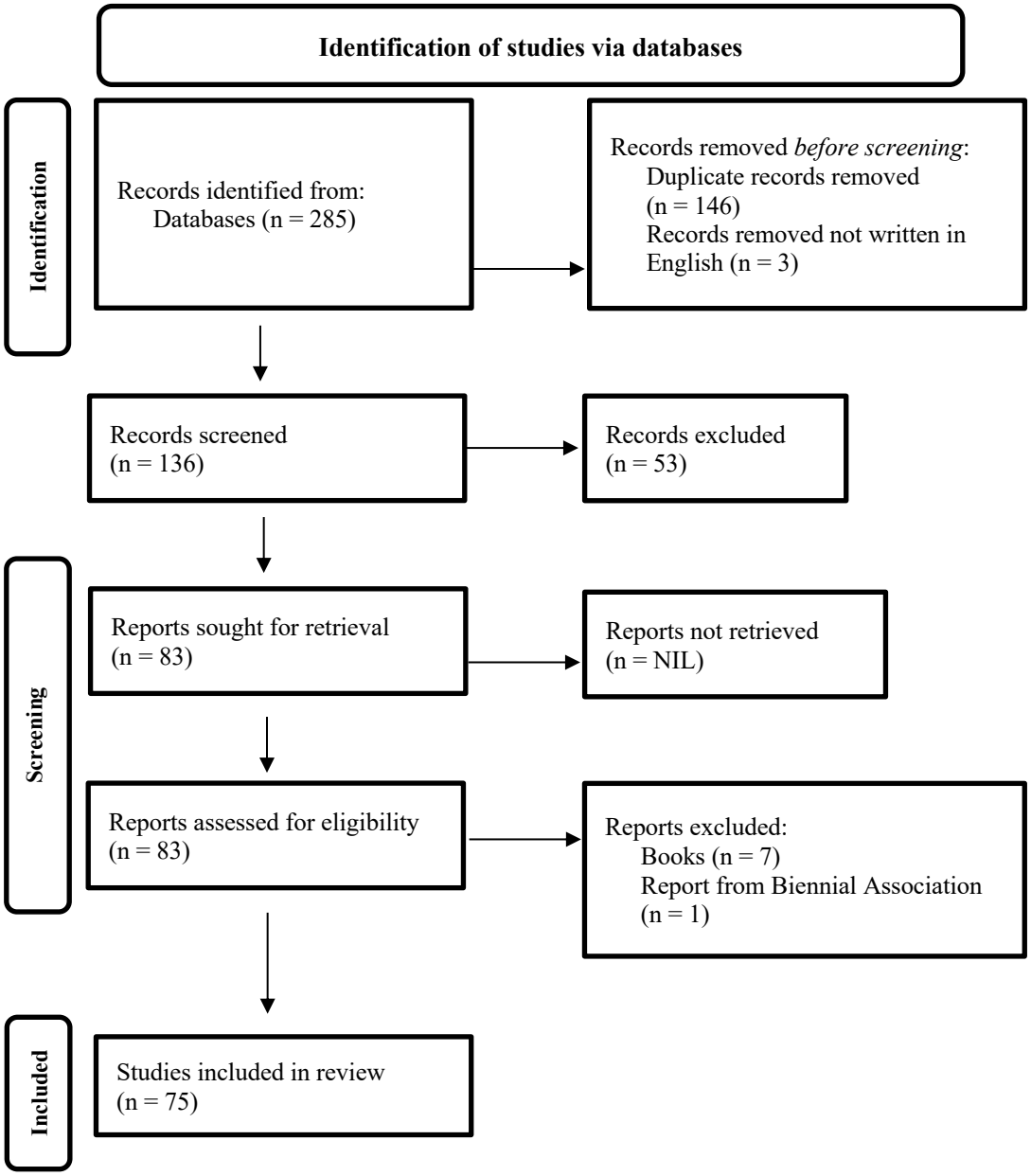
Methodology

Search Procedures, Data Collection, and Data Management

A systematic search was conducted using five popular databases, ERIC, Education Source, Child Development and Adolescent Studies, Psyc INFO, and Academic Search Ultimate (McDaniel, n.d.). Keywords "Self-Efficacy" and "Technological pedagogical content knowledge" were used on the EBSCO host platform to identify scholarly peer-reviewed articles published between 2006 and 2021. Searches were limited to peer-reviewed journal articles published in English, which excludes book chapters, conference proceedings, and published or unpublished dissertations. The title, abstract, and keywords of each article from the initial search, which resulted in 285 articles (75 in Social Sciences Citation Index, 81 in Education Resources Information Center, and 129 in Scopus), were read carefully. Finally, 136 non-overlapping articles comprising empirical studies were selected for further investigation. After screening all 136 results, 75 articles were selected for the present study (Figure 1). The article categorization, inclusion, and exclusion criteria are presented in the forthcoming sections.

Figure 1

Flow Diagram ("PRISMA 2020 statement: An updated guideline for reporting systematic reviews," 2021)



Article Categorization

The content analysis approach (Bryman, 2015), which comprises qualitative and quantitative methods, was adopted for a critical screening of the 75 peer-reviewed studies (Figure 1). Content analysis steps included shortlisting articles with the title "Technological pedagogical content knowledge" or "TPACK" or "TPCK", screening abstracts to confirm empirical studies with appropriate

methods, and finally reading whole articles. Articles were double-scanned for the identifying approaches used (self-report or skill performance-based), subject domains, and grade levels.

The protocol developed for examining article characteristics included the year of publication, author(s), research methodology (quantitative, qualitative, and mixed methods), subject domains, selected samples (pre-service teacher, in-service teachers, and others), approaches used (self-report and skill performance-based), and the title of the study.

Inclusion and Exclusion Criteria

After reading the abstracts of all 136 peer-reviewed articles, 75 relevant articles were selected to include in the study.

The following inclusion criteria were used:

1. Peer-reviewed journal articles focusing on teachers' self-efficacy in developing and implementing TPACK as a framework.
2. Articles examining the impact of professional developmental practices on TPACK self-efficacies and on teacher effectiveness.
3. Articles investigating teachers' TPACK literacy, perception, and belief.
4. Article published in English.

The following exclusion criteria were used:

1. Editorial, letters, opinions, conference papers, and dissertations.
2. Articles not published in English.

Results

This section could provide data on research methods, study samples, subject domains, and evaluation approaches used in the TPACK studies to date.

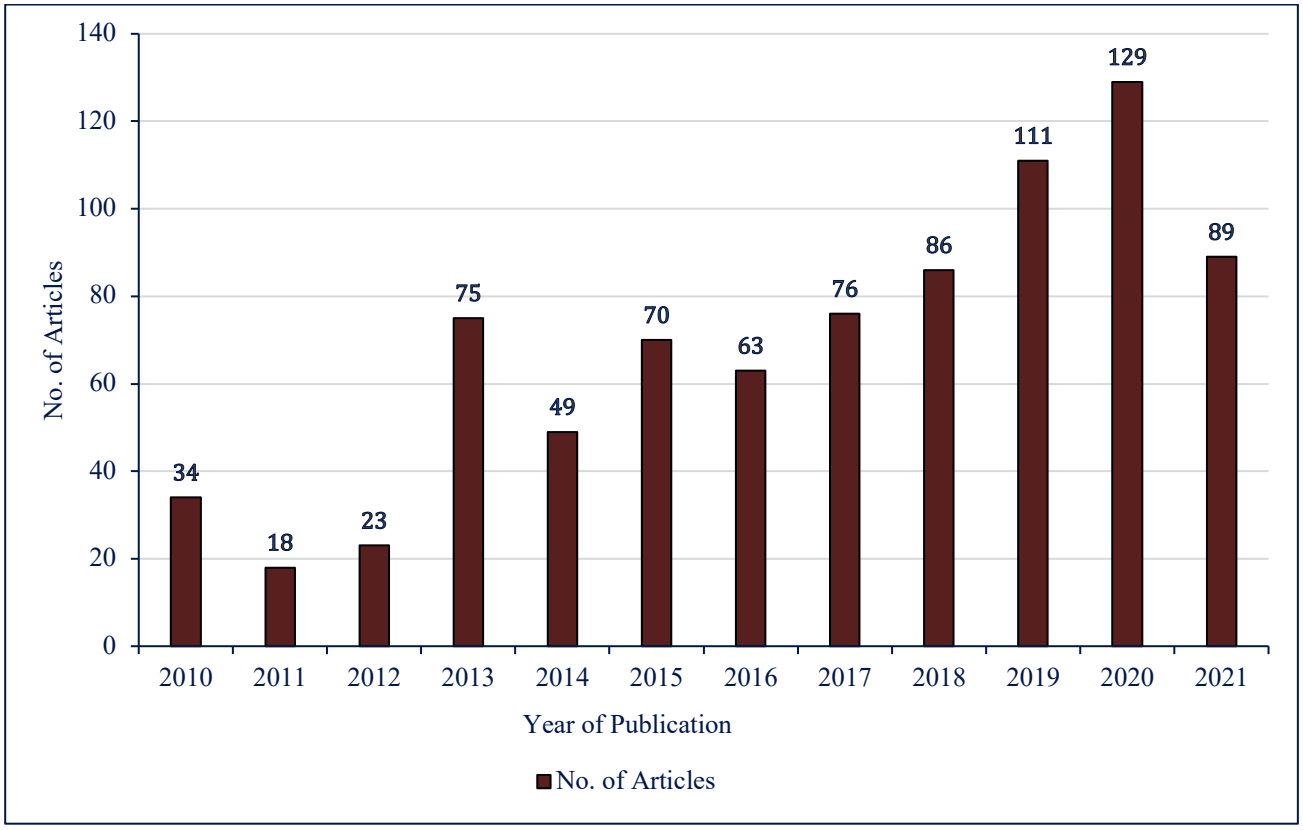
Year-Wide Appearance of TPACK and Self-Efficacy and Self-Efficacy Studies

TPACK framework caught the attention of researchers since its inception in 2005, but there was a noticeable upsurge in the appearance of empirical TPACK studies during 2010, which was around a 21% increase in the total TPACK studies published between 2005-2009 (Figure 2). This sudden rise in numbers went down in the year 2011, however, kept rising after 2012. This rising trend showed that the TPACK framework was discussed well in the last decade and continues to be an interesting framework for researchers.

The largest number of TPACK articles was published in 2020 with the volume expected to rise in 2021 as 89 articles were already published by the time this study was conducted. These rising trends have been crucial for the establishment of TPACK as a framework.

Figure 2

Year-Wide Distribution of Empirical TPACK Publications

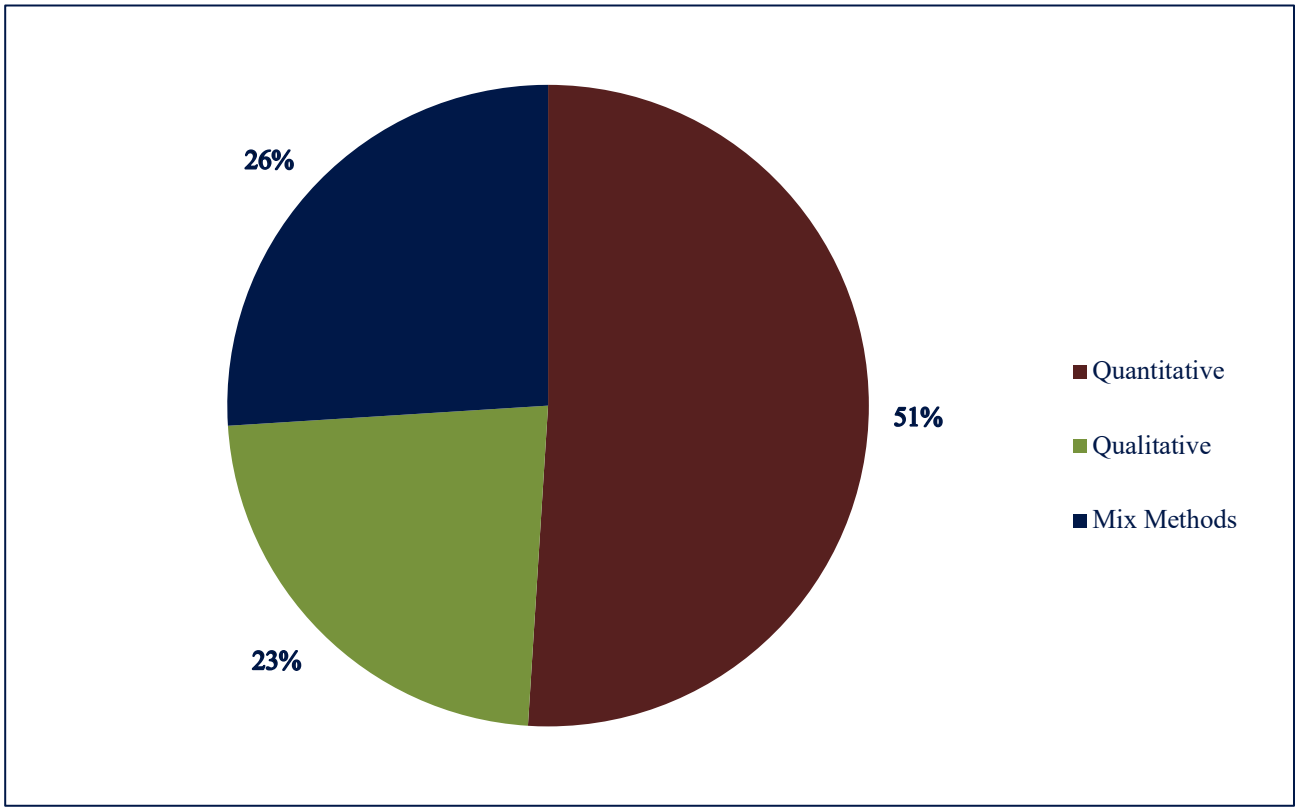


Research Methods Used in TPACK and Self-Efficacy Studies

In previous TPACK studies, quantitative, qualitative, and mixed-methods were adopted. As shown in Figure 3, more than half of the studies have adopted the methods based on quantitative design. These studies have used surveys, polls, and questionnaires for data collection. Of the studies, 23% have adopted the methods based on qualitative design. These studies have used interviews, group discussions, group activities, observations, and content analyses. The remaining 26% of the studies have adopted the methods based on mixed design.

Figure 3

Method-Wide Distribution of Empirical TPACK Studies



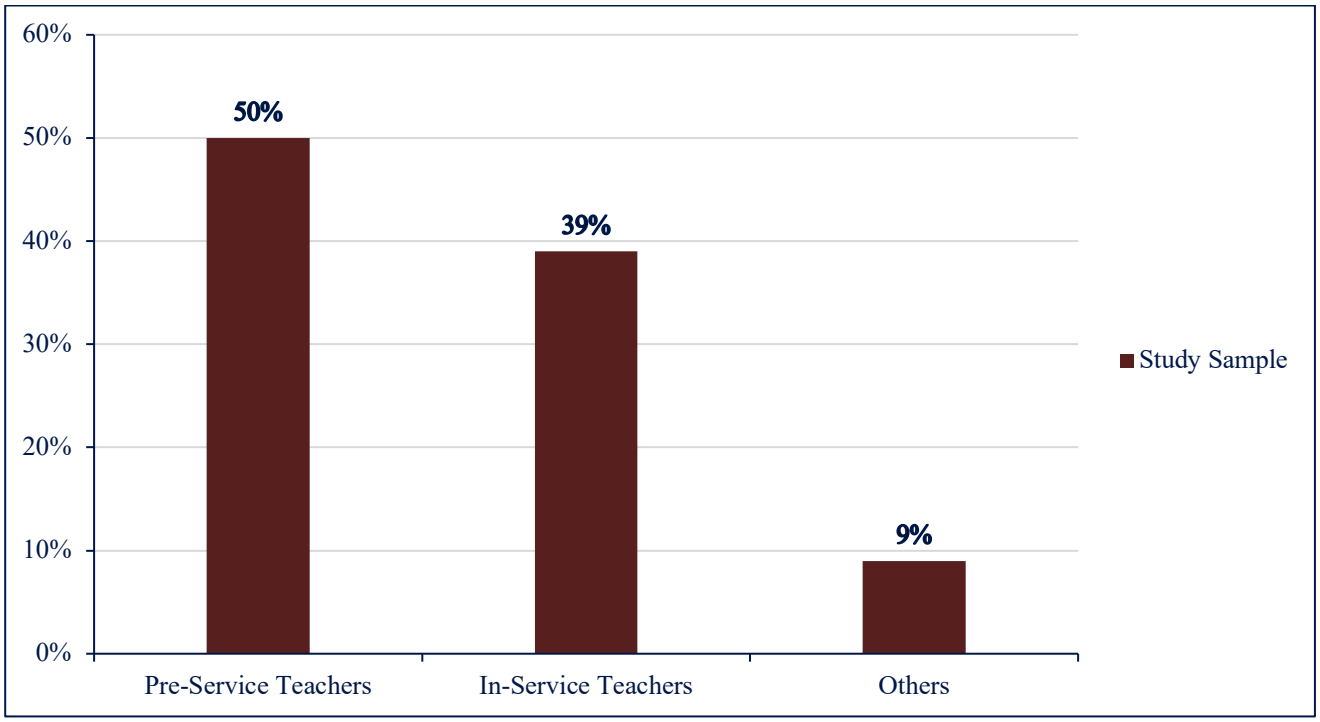
Study Samples Used in TPACK and Self-Efficacy Studies

Study samples included pre-service teachers, in-service teachers, and other academics. From all the TPACK studies, 50% have recruited pre-service teachers, 39% have recruited in-service teachers, and 2% have recruited both pre-and in-service teachers. Of the studies, 9% recruited samples from other groups of academics such as school principals, school representatives, tutors, engineering students, high school students, and graduate and undergraduate students.

From pre-service teachers, 26% of the samples were recruited from elementary schools (grades 1-6), 46% from high schools (grades 7-12), and 21% were recruited from colleges and universities. The remaining 7% were recruited from a non-teaching background. From in-service teachers, 26% of the samples were recruited from elementary schools (grades 1-6), 56% from high schools (grades 7-12), and 18% were recruited from colleges and universities.

Figure 4

The Sample-Wide Distribution of Empirical TPACK Studies

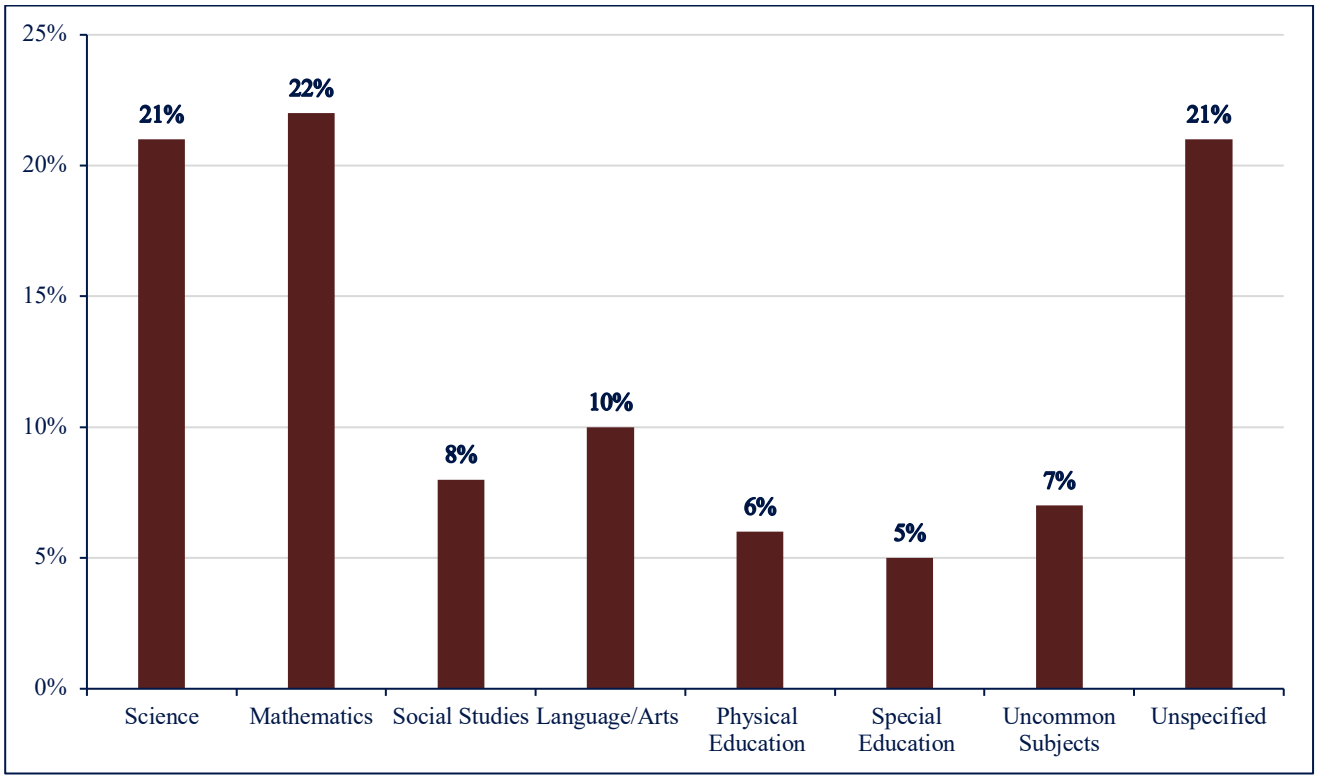


Subject Domains Used in TPACK and Self-Efficacy Studies

TPACK was administered as a framework in various subject domains. These subject domains were science (21%), mathematics (22%), social studies (8%), language/arts (10%), physical education (6%), and special education (5%). Of the studies, 7% have analyzed TPACK for the subject areas such as jewelry technology, music, tech integration courses, educational technology course, engineering, and education. Among these subject domains, jewelry technology, music, and education were the uncommon subject domains, which appeared in one or two studies. The subject areas were unspecified in the remaining 21% of the TPACK studies.

Figure 5

Subject-Wide Distribution of Empirical TPACK Studies

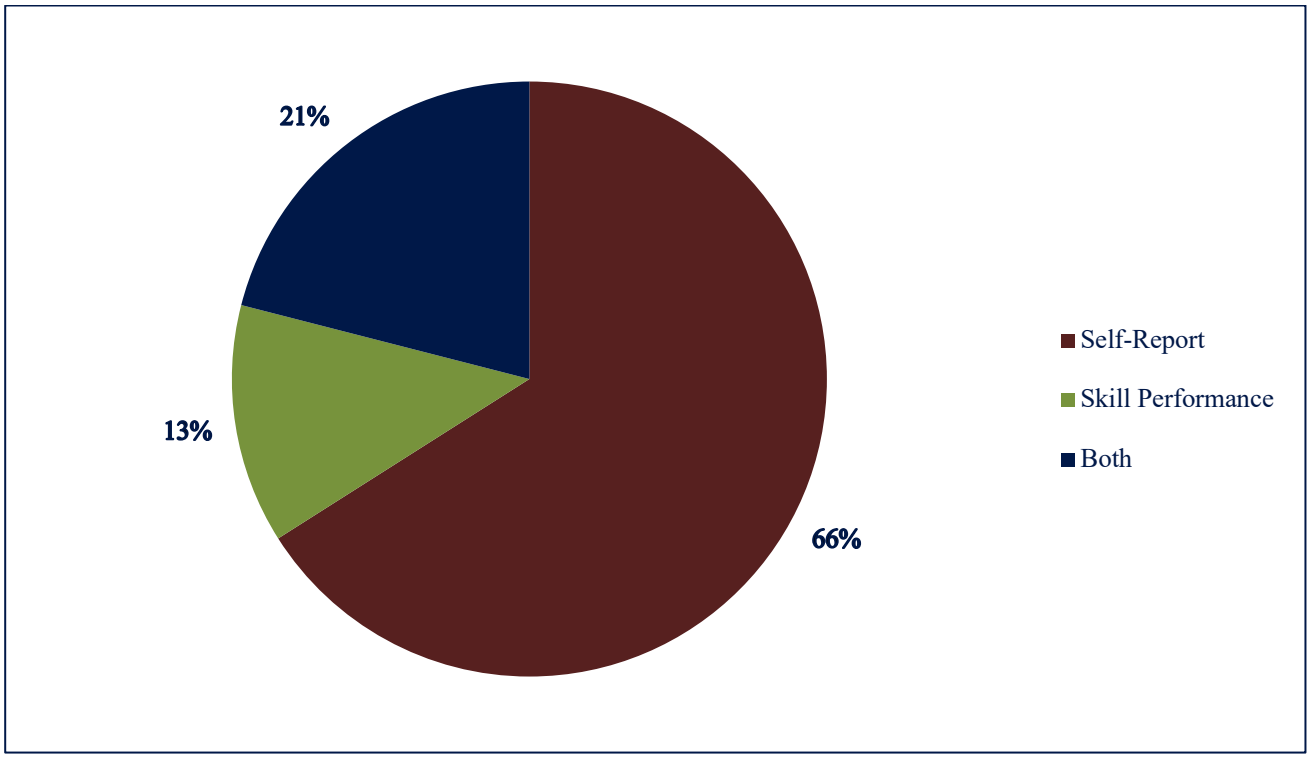


Evaluation Approaches Used in TPACK and Self-Efficacy Studies

The evaluation approaches were analyzed in terms of two categories: self-report and skill performance (performance on teaching activity), as described by Willermark (2017). From all the TPACK studies, 66% of the studies have employed self-report, 13% of the studies have employed skill performance activities, and 21% of the studies have employed both approaches. The use of self-report measures decreased in the last five years (2016 - 74%; 2021 - 58%) whereas the use of skill performance measures was increased (2016 - 12%; 2021 - 14%). Further, the use of combined approaches was reduced substantially (2016 - 28%; 2021 - 14%).

Figure 6

Evaluation Approaches Used in the Empirical TPACK Studies



Discussion

The outcomes of this study could be described in clusters, guided by specific themes. The first cluster could describe the growth of TPACK in terms of research methods, study samples, subject domains, and evaluation approaches. Other clusters (5.2 – 5.8) could describe research-based findings from TPACK-based professional development opportunities. These clusters could also explain best practices that were employed while implementing TPACK into teaching-learning and professional development practices, which could help educators improve their technology self-efficacy.

Growth of TPACK

The results of this study indicated that TPACK has grown tremendously in the last decade in terms of research methods, study samples, subject domains, and evaluation approaches. The number of empirical studies has increased over the years and these results align with the outcomes from previous studies (Willermark, 2017). Quantitative, qualitative, and mixed methods were used for analyzing the impact of tech-based professional development on teachers' self-efficacy. The samples included pre-service and in-service teachers, however, professionals from the administration were also recruited as samples in some of the studies. There was a wide range of subject domains in which TPACK was examined such as science, mathematics, social studies, language/arts, physical education, special education, jewelry technology, music, tech integration courses, educational technology course,

engineering, and education. In these studies, TPACK was evaluated using two key approaches: self-report and skill performance (performance on teaching activity). Such analysis provided fascinating data about the growth and development of TPACK approaches, which could serve as a guiding document for the researchers. Also, the analyses in terms of research methods, study samples, subject domains, and evaluation approaches could guide researchers in choosing the appropriate study variables for future studies. A comparative analysis of self-report and skill performance-based studies holds promise in directing researchers to adopt factual approaches for future TPACK studies.

TPACK evolved as one of the useful frameworks addressing the successful integration of technology into classroom instruction (Koehler & Mishra, 2008). TPACK was measured in numerous studies using diverse samples and approaches to explore the framework further (Altun, 2019; Bingimlas, 2018; Cai et al, 2019; Fathi & Yousefifard, 2019; Koehler et al., 2014; Zahwa et al., 2021). TPACK's widespread impact was criticized for inaccurate and insufficient definitions of knowledge domains as well as the integration of the technology domain into the model (Anderson et al., 2001; Cox & Graham, 2009; Graham, 2011). Nevertheless, TPACK has grown into an influential framework through diverse educational settings and interventions (Angeli & Valanides, 2009; Baran et al., 2011; Oda et al., 2020; Polly, 2011; Young et al., 2019). Despite the ample attention that TPACK has received, it was rarely applied in studies incorporating ongoing activities in order to strengthen performance in teaching and professional development interventions (Willermark, 2017).

The Impact of Tech-Based Professional Development Interventions on Teachers' TPACK Self-Efficacy

Technology Interventions and TPACK Self-Efficacy

Technology-based professional development interventions had a huge impact on teachers' self-efficacy. Well-developed design and skill performance-based interventions were found to be helpful for teachers in building their TPACK self-efficacies. Professional development programs using technologies such as interactive whiteboards and geographic information systems played a crucial role in determining TPACK and other derivative variables (DeSantis, 2013; Oda et al., 2020). TPACK served as a guiding theory in analyzing the impact of individual knowledge domains, i.e., content, pedagogy, and technology. TPACK was assessed through qualitative studies using staples from elementary language-arts and it was concluded that teachers' approach toward pedagogy was aligned with the use of the iPad in their classrooms (Anderson et al., 2017). Anderson et al. (2017) also found that teachers' pedagogical knowledge and teaching experience strongly influenced the use of mobile technology in the classrooms.

Professional Development Interventions and Self-Efficacy

The participants of the designed-based professional development interventions were likely to build technology self-efficacy and TPACK self-efficacy as the interventions were effective in determining and developing TPACK and other tech-based frameworks such as Instructional Technology Outcome Expectations and Technology Integrated Self-Efficacy (Cengiz, 2014). Teachers' attitudes toward the integration of technology in different subject areas helped them approach the

pedagogy in these subjects (Simsek & Sarsar, 2019; Simsek & Yazar, 2019). Moreover, teachers' understanding of pedagogy and teaching strategy influenced decision-making toward the use of technology in the classrooms. The relationship between TPACK knowledge and self-efficacy was identified as dynamic as this relationship varied with the content and setting (Cengiz, 2014). The qualitative methodology may be a good fit to assess some of the TPACK variables. However, the data collection techniques such as questionnaires may pose some limitations to the qualitative studies.

Professional development interventions from technology integration courses had a statistically significant impact on the TPACK self-efficacy beliefs of pre-service teachers and individual dimensions such as content knowledge (CK), pedagogical content knowledge (PCK), and technological pedagogical knowledge (TPK) predicted the outcomes for their overall TPACK (Abebe et al., 2022). Despite the huge benefit of technology integration into classrooms, teacher practitioners had limited use of it in English as a foreign language (EFL) courses. While investigating issues with technology integration, Zhang and Chen (2022) discovered that affective attitudes of teachers were unrelated to their technology use. However, both TPACK and evaluative attitudes had a positive impact on the actual technology use in both online and face-to-face classes. Teachers from other language courses such as Chinese as a second language (CSL) also reported problems with the integration of technology into the curriculum as they were least confident about their technology use (Qiu et al., 2022). Further, the CSL teachers were not able to distinguish the boundaries between the dimensions such as TPK, TCK, and overall TPACK. However, the TPACK proficiency and skills of teachers from engineering courses were found to be good (Ferdiansyah et al., 2022). These studies warranted a need for examining TPACK self-efficacy across subjects. In conclusion, professional development interventions had a positive impact on teachers' TPACK self-efficacies and helped teachers to get a better understanding of the existing content, pedagogy, and technology knowledge by focusing on key areas, which further helped fulfill the needs of the 21st century classrooms.

TPACK as the Predictor of Self-Efficacy

TPACK knowledge was found to be one of the predictors of self-efficacy beliefs in the empirical articles reviewed in this study (Birisci & Kul, 2019; Cankaya, 2018; Kan & Yel, 2019). However, participants were not confident in their ability to design and implement content-based materials using technology (Abbitt, 2011; Cengiz, 2014; Saudelli & Ciampa, 2016; Wetzel et al., 2014). TPACK-based courses in natural sciences (science education and math) and literature were helpful in improving teachers' self-efficacies (Tokmak & Incikabi, 2013). It was interesting to know that there was a significant difference between the self-efficacies of teachers teaching natural science and social science toward their teaching and technology-content knowledge. However, this difference was not significant for the TPACK. The TPACK for 21st century learning program (TPACK-21CL) professional developmental processes were found to be generally effective for enhancing teachers' TPACK-21CL confidence and their confidence in design (Koh et al., 2016). This study had limitations such as school level (elementary), single-cycle lesson redesign, and construct validation of the survey instrument. These limitations make the study results restricted on one hand but open doors for future research on the other hand. Focusing on coherent groups, time duration, and an absence of timely follow-up may be the additional limitations to all the studies reviewed.

Skill-Performance Interventions and TPACK

TPACK-based argumentation practices were also found to be effective in increasing participants' TPACK self-efficacy in addition to changing participants' views toward the argument statements (Çoban et al., 2016). TPACK for 21st century learning program was found to be effective in enhancing technology self-efficacy of both students and teachers (Koh et al., 2016). The process included 37 primary school teachers' (from subject areas English, Mathematics, and Science) and described their prolonged engagement with peers and researchers within the teams for one school year. Another training program that was based on TPACK-based argumentation interventions had a noticeable positive impact on the participants (Çoban et al., 2016). Such skill-performance-based interventions may help fill the gap between the theory and the practice. In all the studies reviewed, participants were able to connect with the TPACK components toward the end of the intervention.

Computer Literacy and TPACK Self-Efficacy

Computer literacy played a key role in performance development interventions as the computer self-efficacy of teachers was closely associated with cognitive style and TPACK self-efficacy (López-Vargas et al., 2017). Computer literacy also played a significant role in assessing the integration of technology into pedagogy as the self-efficacy of computer literate teachers was predominantly higher in using technology in classrooms (Bakar et al., 2020; Coyne et al., 2017). However, the perceptions of teacher self-efficacy and academic self-efficacy changed with different variables such as gender, age, grade point average, and subject areas (Berkant & Baysal, 2018). Factors such as perceived ease of use and perceived usefulness of technology in classrooms also affected teachers' intentions to use technology (Joo et al., 2018). Self-efficacy was sometimes misunderstood with overconfidence as there was a difference between self-perception of teachers' content knowledge and teaching abilities to the perception of their supervisors (Dassa & Nichols, 2019). Nevertheless, the self-efficacy beliefs of teachers were closely associated with their attitudes about computer-assisted instructions (Kan & Yel, 2019), which was an indication of improved computer literacy.

Sustainability of TPACK-Based Professional Development Interventions

TPACK was evaluated for the sustainability of professional development interventions fostering one-to-one technology support (Kerry, 2019). The study was based on Bandura's (1997) self-efficacy theory and found that "content-driven professional development, clear expectations for technology use in classrooms, and the availability of school-based instructional coaches can impact the sustainability of a one-to-one computing initiative" (p. 17). Factors such as school climate and teachers' attitude were the key components for the integration of technology in classrooms (Raygan & Moradkhani, 2020). Teachers' attitudes in technology integration strengthened the association between technology competency and TPACK competency (Yulisman et al., 2019). Moreover, teachers' attitudes toward the use of technology played a moderating role between technology competency and TPACK competency. Professional development interventions helped mathematics teachers from urban schools improve their perceptions of PK, TK, PCK, and TCK (Young et al., 2020). However, pre-service teachers "considered themselves to have the high-level ability in both digital nativity and TPACK competency"

(Kabakci-Yurdakul, 2018, p. 267). Nevertheless, the notion of TPACK development was different for both pre-service and in-service teachers, and prior experience of technology influenced their use of technology in classrooms (Akapame et al., 2019).

Research-Based Practices to Improve Technology Self-Efficacy

Research indicated that computer literacy played a key role in improving teachers' self-efficacy. Teachers with well-informed computer knowledge have had higher technology self-efficacy than teachers with low computer knowledge. Therefore, reinforcing robust computer literacy in educational institutions could be the basic research-based professional development practice to improve the technology self-efficacy of teachers. TPACK-based classroom practices helped both teachers and learners improve their self-efficacy toward the integration of technology into the curriculum. On one hand, such practices helped teachers improve their self-confidence toward the use of technology in day-to-day teaching-learning. On the other hand, these practices helped students develop confidence in the appropriate integration of technology by teachers into the curriculum. Therefore, reinforcing TPACK-based technology integration into classrooms could prove to be another useful practice, which could help improve teachers' self-efficacy. Teachers using self-developed technology-based instructional materials as a teaching strategy are more likely to develop technology self-efficacy than teachers who do not use such materials. Therefore, subject-based professional development practices for the integration of technology into the curriculum should help teachers improve their technology self-efficacy.

Skill performance-based and practice-based technological interventions can be one of the most influential practices to improve teachers' technology self-efficacy as these practices helped teachers in building their TPACK self-efficacies. Professional development programs providing hands-on technologies such as interactive whiteboards, smartboards, classroom tablets, Listserv, learning management systems, online quiz makers, PowerPoint slideshows and games, online grading systems, geographic information systems, etc. can be highly useful. Designed-based professional development interventions and TPACK-based argumentation practices helped teachers become classroom tech-savvy and improve their technology self-efficacy, therefore, can be highly useful. Professional development practices based on existing technological frameworks and argumentation practices can help teachers improve their technology self-efficacy as these frameworks provide a strong research-based design for the implementation of technology into the curriculum.

Limitations

This study presented a detailed analysis of the TPACK and its acceptance as a framework, however, may contain some limitations. The first limitation was the keyword combination that was used for the literature search. The database search with the keyword "technological pedagogical content knowledge" provided a large number of outcomes, but these numbers were reduced when another keyword "self-efficacy" was included with the previous keyword. The second limitation was posed by the study inclusion criteria. This systematic review included only empirical studies focusing on the

variables such as tech-based professional development, self-efficacy, and TPACK. The third limitation may be the databases. This study was conducted using databases such as ERIC, Education Source, Child Development, and Adolescent Studies, Psyc INFO, Academic Search Ultimate, and Scopus. The empirical studies beyond the scope of these databases were automatically excluded.

Implication For Future Research

The outcomes of this study indicated that there is a strong need to conduct follow-up studies using contemporary technological tools that can support existing findings concerning TPACK. Extending the studies using new variables would explore new dimensions of TPACK. Professional developmental activities focusing on teacher proficiency, teaching methods, and assessment techniques would help participants understand the TPACK domains better. Qualitative studies using different settings and methods might help both participants and researchers to look at the framework from a different perspective. Studying the relationship between the knowledge domains within the framework for different settings could assist academics to devise an empowered mechanism for implementing tech-based practices. Strategies developed from the TPACK-aligned interventions may be useful for many faculty-leadership programs as well as for tech-based professional development programs.

One of the key areas for future research would be validating the existing outcomes in other schools/levels, colleges, and tertiary institutions. The school leadership culture and its impact on implementing the professional development process could be further examined. In future research, the prolonged effects of developmental processes on teachers' TPACK-21CL design confidence can be examined across multiple redesigned cycles. Further work in the areas of design-based scaffolding can be done to enhance teacher learning in school-based contexts.

Teacher preparation programs can have the usefulness of the relationship that pedagogical knowledge has with the knowledge evolution of the participants when they switch from preservice to in-service. Understanding various uses of technology in the educational arena may help teachers better prepare for their classrooms. Scaffolding during training programs could assist teachers in developing a sound technical background and tech self-efficacy. Design-based TPACK studies could enhance teachers' basic technology skills and might be evidence for future TPACK studies. Argumentation-based TPACK studies promote understanding the deep epistemology of the framework. Furthermore, future plans include studying the impact of online or face-to-face content delivery on students' TPACK self-efficacies using pre-test-post-test design.

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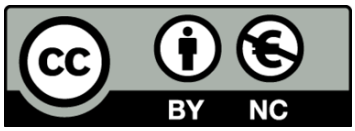
Authors

Suresh C. Joshi is Professor of Learning Design and Technology and Organizational Behavior. Currently he is working as Executive Director of the Centre for Distance and Online Learning at Chandigarh University, Punjab, India. His research interests include instructional design and technology, artificial intelligence, metaverse, pedagogical innovations, social-emotional learning, self-regulation, psychological well-being, and leadership in crisis. His PhD research revolved around developing a theoretical framework for the correlation between cell phone use and sleep quality, academic performance, and psychological well-being. Dr. Joshi is a certified instructor from the Center for Teaching Excellence at Texas A&M University, USA. He has developed a teaching model based on low-cost pedagogical game tools for which he was awarded a Fulbright fellowship from the US Department of State. He has published around 40 research papers and four books. *Email:* contactscjoshi@gmail.com



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A Comparison Between Virtual and Conventional Microscopes in Health Science Education

Comparaison entre les microscopes virtuels et conventionnels dans l'enseignement des sciences de la santé

Nazlee Sharmin, University of Alberta

Ava K. Chow, University of Alberta

Alice S. Dong, University of Alberta

Abstract

Virtual microscopes are computer or web-based programs that enable users to visualize digital slides and mimic the experience of using a real light microscope. Traditional light microscopes have always been an essential teaching tool in health science education to observe and learn cell and tissue structures. However, studies comparing virtual and real light microscopes in education reported learners' satisfaction with virtual microscopes regarding their usability, image quality, efficiency, and availability. Although the use of virtual or web-based microscopy is increasing, there is no equivalent decrease in the number of schools utilizing traditional microscopes. We conducted a scoping review to investigate the comparative impact of conventional and virtual microscopes on different aspects of learning. We report a relative effect of virtual and light microscopy on student performance, long-term knowledge retention, and satisfaction. Our results show that virtual microscopy is superior to traditional microscopes as a teaching tool in health science education. Further studies are needed on different learning components to guide the best use of virtual microscopy as a sole teaching tool for health care education.

Keywords: virtual microscope; web-based microscope; health science education; learning experience

Résumé

Les microscopes virtuels sont des programmes informatiques ou web qui permettent aux utilisateurs de visualiser des diapositives numériques et d'imiter l'expérience de l'utilisation d'un

vrai microscope optique. Les microscopes optiques traditionnels ont toujours été un outil d'enseignement essentiel dans l'enseignement des sciences de la santé pour observer et apprendre les structures cellulaires et tissulaires. Cependant, des études comparant les microscopes virtuels et optiques dans l'éducation ont rapporté la satisfaction des apprenants à l'égard des microscopes virtuels en ce qui concerne leur convivialité, leur qualité d'image, leur efficacité et leur disponibilité. Bien que l'utilisation de la microscopie virtuelle ou web augmente, il n'y a pas de diminution équivalente du nombre d'écoles utilisant des microscopes traditionnels. Nous avons effectué un examen de la portée pour étudier l'impact comparatif des microscopes conventionnels et virtuels sur différents aspects de l'apprentissage. Nous rapportons un effet relatif de la microscopie virtuelle et optique sur la performance des étudiants, la conservation des connaissances à long terme, et la satisfaction. Nos résultats montrent que la microscopie virtuelle est supérieure aux microscopes traditionnels en tant qu'outil d'enseignement dans le domaine de l'enseignement des sciences de la santé. D'autres études sont nécessaires sur différentes composantes d'apprentissage pour guider la meilleure utilisation de la microscopie virtuelle comme seul outil d'enseignement pour l'éducation en matière de soins de santé.

Mots-clés : microscope virtuel ; microscope basé sur le web ; enseignement des sciences de la santé ; expérience d'apprentissage

Introduction

Traditional light microscopes have always been used for teaching tissue structures and microanatomy in health science education. Recent advancements in whole-slide imaging, virtual microscopes, digital slide viewers, and similar technologies show an immense possibility in education, with a potential to entirely substitute traditional light microscopes in many disciplines of health science education (Saco et al., 2016; Triola & Holloway, 2011). *Virtual* or *web-based microscope* refers to a computer or web-based program that enables users to mimic the experience of using a real light microscope. A virtual microscope allows users to view, navigate, and manipulate digital slides acquired from a camera-equipped microscope or a commercial digital slide scanning system (Triola & Holloway, 2011). The popularity and use of virtual microscopes are increasing throughout health professional education, especially in histology and pathology (Bloodgood & Ogilvie, 2006; Glatz-Krieger et al., 2006; Paulsen et al., 2010; Sharmin et al., 2021). Virtual microscopes improve the overall in-class teaching environment (Blake et al., 2003; Bloodgood & Ogilvie, 2006; Cotter, 2001; Kumar et al., 2004). Studies comparing virtual and real light microscopes in education found equal satisfaction from learners with the quality of image and usability while garnering greater satisfaction with the efficiency of learning and availability (Harris et al., 2001; Heidger et al., 2002; Kumar et al., 2004; Mills et al., 2007). Students' academic performances are improved or unaffected by virtual microscopy (Harris et al., 2001; Helle et al., 2013; Kumar et al., 2004).

One of the critical advantages of a web-based or virtual microscope over a traditional light microscope is its ubiquitous availability (Triola & Holloway, 2011). This technology allows users to view digital slides anytime and at any place in the world, outside the classroom. The traditional method of teaching microanatomy and tissue structure relies on a limited number of light microscopes and glass slides, which does not allow simultaneous observation by multiple learners, prevents interactive in-class discussions. As per Capela et al. (2010), these limitations attenuate student motivation. Virtual microscopes enable multiple users to view the digital slides on a larger screen, promoting interactive discussion and team-based learning (Triola & Holloway, 2011). Digital slides and virtual microscopes can also be excellent resources for teaching. Instructors can pre-annotate slides outside class time and embed digital slides or links to specific views in teaching notes (Harris et al., 2011).

Although virtual microscopes and other computer-based slide-viewers provide access to many great-quality rare slides, they require computers, active Internet, or other smart devices, which may not be readily available to everyone. Although the use of virtual or web-based microscopy is increasing, there is not an equivalent decrease in the number of schools utilizing traditional microscopes for education (Bloodgood & Ogilvie, 2006), indicating that the questions regarding the impact of virtual microscopes in all aspects of learning are yet to be answered.

In this context, we aim to investigate the current scenario of virtual microscopy in health professional education, with a specific focus on the comparative impact of traditional and virtual microscopes in different aspects of learning. Our research question is: *How do virtual microscopes compare with conventional microscopes in health science education?*

Methods

Data Sources

Both medical and allied health databases were searched systematically to include all health professional education programs at the graduate and undergraduate levels. PubMed, The Cumulative Index to Nursing and Allied Health Literature (CINAHL) database, Excerpta Medica dataBASE (EMBASE), Cochrane, and Web of Science were searched systematically. Search terms were: *virtual histology*, *virtual microscopy*, and *web-based microscopy* combined with *education*, *teaching*, and *learning*. The details of search terms and search results are listed in Table 1.

Study Selection

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were followed to conduct the scoping review (Moher et al., 2009). Figure 1 represents the flow diagram of the study selection. Articles written in English and published in the last 10 years were included. To answer our research question, we included studies solely focused on health professional education. We excluded articles published before 2010, focused on non-

health professional education, or applied virtual microscopy for diagnostic or clinical uses. We also excluded articles that are reviews, commentary, opinions, or technical descriptions. According to our established inclusion criteria, articles were screened based on titles and/or abstracts by two independent reviewers in the first round of review. In the second round, the two reviewers examined the full texts of the selected articles. After each review cycle, the disagreements between the first two reviewers were resolved by the third reviewer. Details of the inclusion and exclusion criteria are listed in Table 2.

Table 1

Detail of Search Terms and Search Results

Search Term	**Databases**				
	EMBASE	**CINAHL**	**Cochrane**	**PubMed**	**Web of Science**
Web-based microscopy AND Education	0	7	4	30	29
Web-based microscopy AND Learning	0	2	3	30	36
Web-based microscopy AND Teaching	0	1	2	38	21
Virtual histology AND Education	0	46	38	424	98
Virtual histology AND Learning	1	22	37	320	112
Virtual histology AND Teaching	0	25	31	388	110
Virtual microscopy AND Learning	2	7	23	107	188
Virtual microscopy AND Education	1	46	26	180	185
Virtual microscopy AND Teaching	0	11	26	338	167
Total	**4**	**167**	**190**	**1,855**	**946**

Table 2

Inclusion and Exclusion Criteria

Selection Criteria	Inclusion	Exclusion
Language	English	Non-English
Year of study	Studies published within last 10 years	Studies published before 2010
Study focus	Health professional education	Non- health professional education
	Education: Didactic/theory/academic classroom teaching and learning	Clinical Use: Diagnostic/surgical/ clinical
	Undergraduate post-secondary education	K-12 education
	Examines user experience and/or learning outcomes	Descriptive and technical articles, review, commentary/opinion articles
Study design	Any	Nil
Setting	Any	Nil

Data Extraction

The data from the 13 articles were extracted and organized (Table 3). The results relevant to the research question were then synthesized.

Results

The initial search included 1,112 non-duplicate records from both medical and educational databases. The first screening phase by title and abstract retrieved 55 articles for full-text review. Forty-two reports were excluded in the second phase for not matching our research question or not conducting a comparative evaluation between virtual and conventional microscopes for education. Duplicates and conference proceedings were also excluded in this phase (Figure 1). After the two-phase screening, 13 articles were eligible for data extraction. All the qualified articles conducted a comparative assessment between traditional and virtual microscopes to teach health professional education.

All the studies included in our review divided research participants into either two or all of the following groups:

Groups using conventional microscopes

Groups using virtual microscopes

Groups using both traditional and virtual microscopes

Twelve studies evaluated students' performance and knowledge attainment. Knowledge acquisition was assessed and compared between the groups from scores in formal board exams (Nauhria et al., 2019), online, multiple-choice, laboratory exams, identification tests (Lee et al., 2020), and score improvement from pre-test to post-test (Hande et al., 2017; Mione et al., 2013; Nauhria et al., 2019). Six studies assessed participants' preferences and satisfaction on the Likert scale. Eleven studies took the quantitative, and two studies took the mixed-method approach to collect and analyze data from the participants.

Figure 1

Flow Diagram Explaining the Study Selection Process

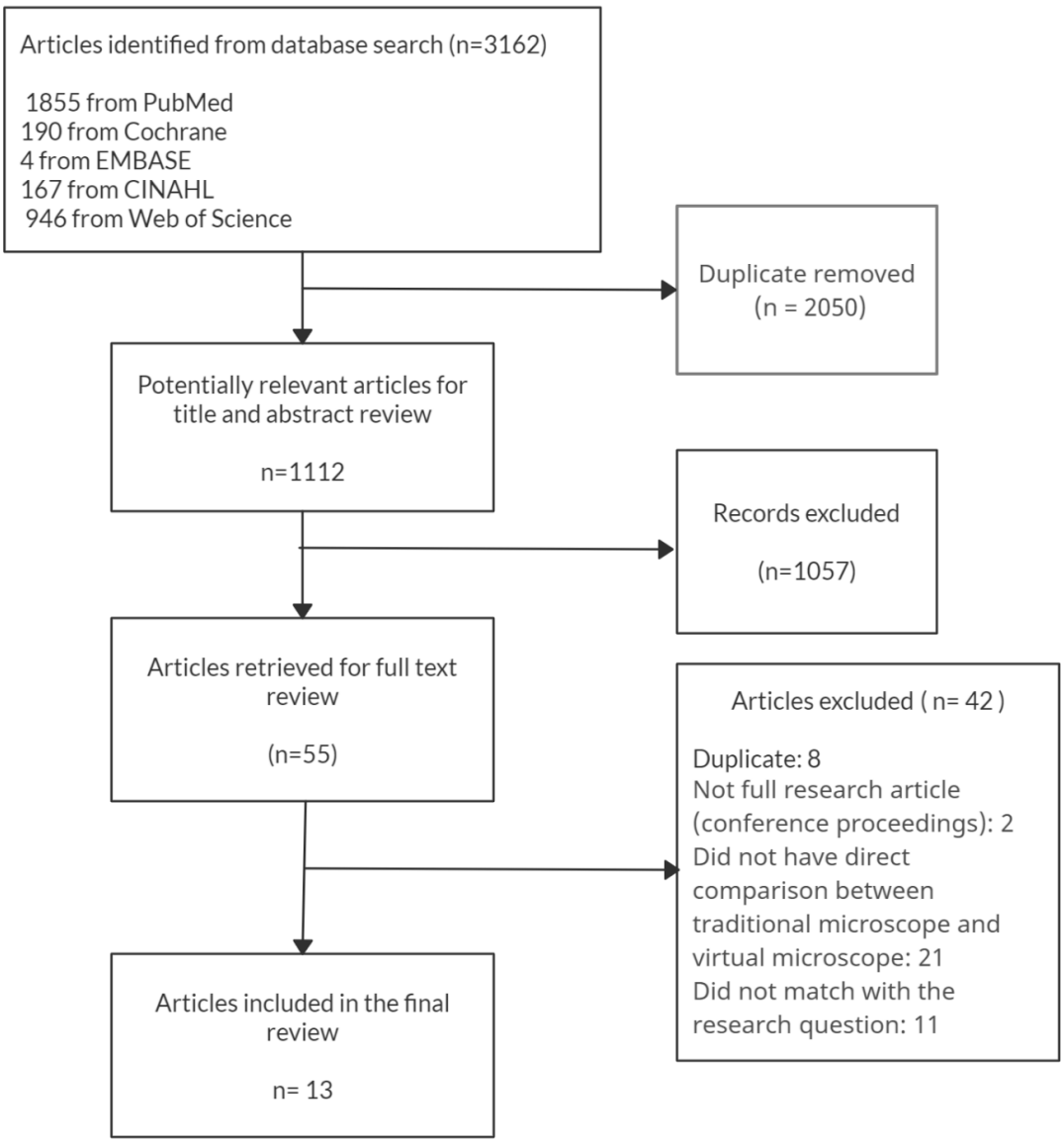


Table 3

Detail of the Studies Included in the Scoping Review

Author, Year, Country	Research Method	Discipline of Health Science Education	Research Aim / Question	Research Participants	Brief Description of the Study	Key Findings	Theme
Mione et al., 2013 Belgium	Quantitative	Histology	To study the impact of the implementation of VM versus LM on the acquisition of histology knowledge.	The study included three different student populations: 1st-year bachelor students in Biomedical Sciences 2006–2007 (n = 172), 1st-year bachelor students in Biomedical Sciences 2007–2008 (n = 202), and 1st-year bachelor students in Logopaedic and Audiological Sciences 2007–2008 (n = 104). Total 478	A pretest-posttest and cross-over design was adopted. In the first phase, students were divided into two groups. Group 1 performed the practical sessions with the LM. Group 2 performed the same sessions with the VM. In the second phase, the research subjects switched conditions. The prior knowledge levels of all students were assessed with a pre-test. Knowledge acquisition was measured with a post-test after each phase.	No significant differences were reported between pre-test and post-test scores of the student groups. Virtual microscopes are equivalent to optical (light) microscopes.	Knowledge acquisition
Lee et al., 2020 Taiwan	Mixed	Histology and Pathology	To examine the influence of VM on academic performance, and teacher and student perceptions.	662 3rd-year medical and dental students studying histology and 651 4th-year students studying pathology	Students were divided into two groups. The light microscopy group used a LM in 2014 and 2015, while the light microscopy + virtual microscopy group used the VM platform and a LM in 2016 and 2017. Examination scores were compared. Participants were asked to complete a survey and write comments.	The light microscopy+ virtual microscopy group exhibited less score variability on laboratory examinations relative to their mean than the light microscopy group. Both teachers and students agreed that the virtual microscopy platform enhanced laboratory learning.	Academic performance
Nauhria et al., 2019 Grenada	Mixed	Pathology	To investigate whether VM or LM had a higher impact on student learning and performance in histopathology.	2nd-year medical students n = 152	A sequential exploratory mixed method study design was used. A qualitative phase inquiring about student preference for VM or LM was followed by a randomized cross-over	83% of the students preferred to use VM over LM. Students who used VM scored significantly higher in both phases of the cross-over study	Academic performance Student satisfaction

Author, Year, Country	Research Method	Discipline of Health Science Education	Research Aim / Question	Research Participants	Brief Description of the Study	Key Findings	Theme
			Whether students preferred VM over LM.		study. Student preference was measured by an online survey based on a Likert scale. In the cross-over study, students were randomized either to the VM or the LM arm, and their mean scores in standardized exams were compared after using VM and LM.	than those who used LM.	
Sagol et al., 2015 Turkey	Quantitative	Pathology	To evaluate the use of virtual microscopy in practical pathology sessions and its effects on students.	2nd and 3rd-year medical students n = 351	The practical sessions were carried out via virtual slides and the effect of the new technique was investigated at the end of each session.	The evaluation of the ratings showed that the students were easily adapted to the use of virtual microscopy. They found it user-friendly and thought that the opportunity of viewing slides at home was advantageous.	Student satisfaction
Ordi et al., 2015 Spain	Quantitative	Pathology	To determine the impact in student scores when moving from conventional microscopy to virtual microscopy. To assess the students' impressions and changes in study habits regarding the impact of this tool.	Students from a medical school n = 181	The authors evaluated two groups taking the discipline of pathology in the same course, one using conventional microscopy and the other virtual microscopy. The same set of slides used in the conventional microscopy classes was digitized and observed by the students using the Virtuoso viewer. The authors evaluated the skill level reached by the students with an online test.	There were no differences between the two groups in their marks in the online test. Students found the software friendly, easy-to-use, and effective. The most appreciated feature of virtual microscopy was the possibility to access images anywhere and at any time.	Knowledge acquisition Student satisfaction
Foad, 2016 Saudi Arabia	Quantitative	Pathology	To compare students' apprehension of knowledge and skills via LM and VM.	2nd-year medical students n = 40	Students were randomly assigned to use either conventional, light, or virtual microscopy in practical sessions. The students' apprehension of knowledge was	Students in the virtual microscopy group performed better than those in the light microscopy group as reflected by their more-uniform performance and less-scattered grades in both	Knowledge acquisition

Author, Year, Country	Research Method	Discipline of Health Science Education	Research Aim / Question	Research Participants	Brief Description of the Study	Key Findings	Theme
					assessed by written and practical exams. The authors also conducted pre- and post-test comparisons between VM and LM groups.	practical and written exams. Students from VM group showed significant improvement in their post-test scores compared to the other LM group.	
Daniela et al., 2018 Chile	Quantitative	Histology	To evaluate the student's academic performance and perception by learning muscle tissue module in the histology unit, using as a study tool light microscopy and a web application created for histological analysis.	1st-year students of dentistry n = 92	A total of 92 students were randomly divided into two groups. Group 1: 46 students used light microscopes. Group 2: 46 students used digital microscopy. At the end of the experimental phase, each group took a cognitive test which measured their ability to diagnose the various types of muscle tissue and to identify structures. A perception test was conducted after everyone had learned with both systems.	In the cognitive evaluation, the median grades were 5.4 for group 1 and 5.7 for group 2. In the perception survey, 73.24 % considered the VM evaluation fairer. It was concluded that the use of a VM tends to have better results than light microscopy.	Knowledge acquisition Student satisfaction
Brown et al., 2016 United Kingdom	Quantitative	Histology	To compare the effectiveness of virtual microscopy and traditional microscopy in teaching histology.	3rd-year veterinary students from the two universities	3rd-year veterinary students from two different schools completed a simple objective test, covering aspects of histology and histopathology, before and after a practical class covering relevant material presented as either glass slides viewed with a microscope or as digital slides.	There was an overall improvement in performance by students at both veterinary schools using both practical formats. Neither format was consistently better than the other, and neither school consistently outperformed the other. In comparing student appraisal of the use of digital slides and microscopes, digital technology was identified as having many advantages.	Knowledge acquisition Student satisfaction

Author, Year, Country	Research Method	Discipline of Health Science Education	Research Aim / Question	Research Participants	Brief Description of the Study	Key Findings	Theme
Evans et al., 2020 USA	Quantitative	Cytology	To determine whether instruction using VM, compared to CM, is a successful method of training veterinary students to apply cytology in practice (i.e., sing light microscopes).	Veterinary students n = 71	Students who attended a voluntary 3-hour cytology workshop were randomized to receive the same instruction with either VM (n = 35) or CM (n = 36). The control group (n = 22) of students who did not attend a workshop. All students took a post-workshop assessment involving the interpretation of four cases on glass slides with CM, designed to simulate cytology in general practice.	The mean assessment score of the VM group (14.18 points) was significantly higher than the control group, whereas the mean of the CM group was not significantly different from the controls.	Knowledge acquisition
Hande et al., 2017 India	Quantitative	Dental histology	To evaluate the effectiveness of virtual microscopy with conventional microscopy on student learning in dental histology.	Dental students n = 105	Students were included and randomized into three groups: A, B, and C. Group A students studied the microscopic features of oral histologic lesions by conventional microscopy, Group B by virtual microscopy, and Group C by both traditional and virtual microscopy. The student's understanding of the subject was evaluated by comparing pre- and post-test scores.	The difference in scores between Groups A, B, and C at pre-and post-test was highly significant. 87.61% of the students strongly agreed that the virtual microscopy was useful as a practically oriented teaching-learning tool and shows enhanced learning.	Knowledge acquisition Student satisfaction
Solberg, 2012 USA	Quantitative	Hematology	To examine student performance, skill retention and transferability, and self-efficacy beliefs amongst undergraduate MLS students learning cellular morphology with digital versus traditional slides.	Students from medical laboratory science (MLS) n = 74	Participants were randomly assigned to either Group 1 or Group 2. Students in Group 1 used digital slides and in Group 2 used traditional slides for the myeloid maturation lab. Data were collected from three sources: immediate performance evaluation, a delayed performance	Students learning with digital slides performed better on assessments containing only traditional slide specimens than students learning with traditional slides, both immediately following the learning activity and after a	Knowledge acquisition Knowledge/ Skill retention Self-efficacy

Author, Year, Country	Research Method	Discipline of Health Science Education	Research Aim / Question	Research Participants	Brief Description of the Study	Key Findings	Theme
					evaluation, and a self-efficacy measure.	considerable duration of time. Students learning with digital slides also reported slightly higher levels of self-efficacy related to cellular identification.	
Brueggeman et al., 2012 USA	Quantitative	Hematology	To evaluate the efficacy of virtual microscopy as the primary mode of laboratory instruction in undergraduate level clinical hematology teaching.	Students from medical laboratory science (MLS) n = 58	Students were randomly assigned to either traditional microscopy or virtual microscopy instruction. Both groups had access to identical lecture materials. Students participated in three surveys requesting feedback on preparedness, perception, and expectations of the course before, during, and after delivery. All students took identical laboratory practical and written exams mid-term and at the end of the semester.	No significant differences between traditional microscopy and virtual microscopy groups with respect to group means for the midterm laboratory exam, the final laboratory exam, or the course total.	Academic performance
Tian et al., 2014 China	Quantitative	Histology	To describe a VM system for undergraduates and to evaluate the effects of promoting active learning and problem-solving skills.	2nd-year medical students n = 221	Students were divided into two groups. The VM group contained 115 students and was taught using the VM system. The LM group consisted of 114 students and was taught using the LM system. Post-teaching performances were assessed by multiple-choice questions, short essay questions, case analysis questions, and the identification of the structure of the tissue. Students' teaching preferences and satisfaction were	Test scores in the VM group showed a significant improvement compared with those in the LM group. There were no substantial differences between the two groups in the mean score rate of multiple-choice questions and the short essay category; however, there were notable differences in the mean score rate of case analysis questions and identification of the tissue structure. The questionnaire	Academic performance Student productivity Learning efficacy

Author, Year, Country	Research Method	Discipline of Health Science Education	Research Aim / Question	Research Participants	Brief Description of the Study	Key Findings	Theme
					assessed using questionnaires.	results indicate that the VM system improves students' productivity and promotes learning efficiency.	

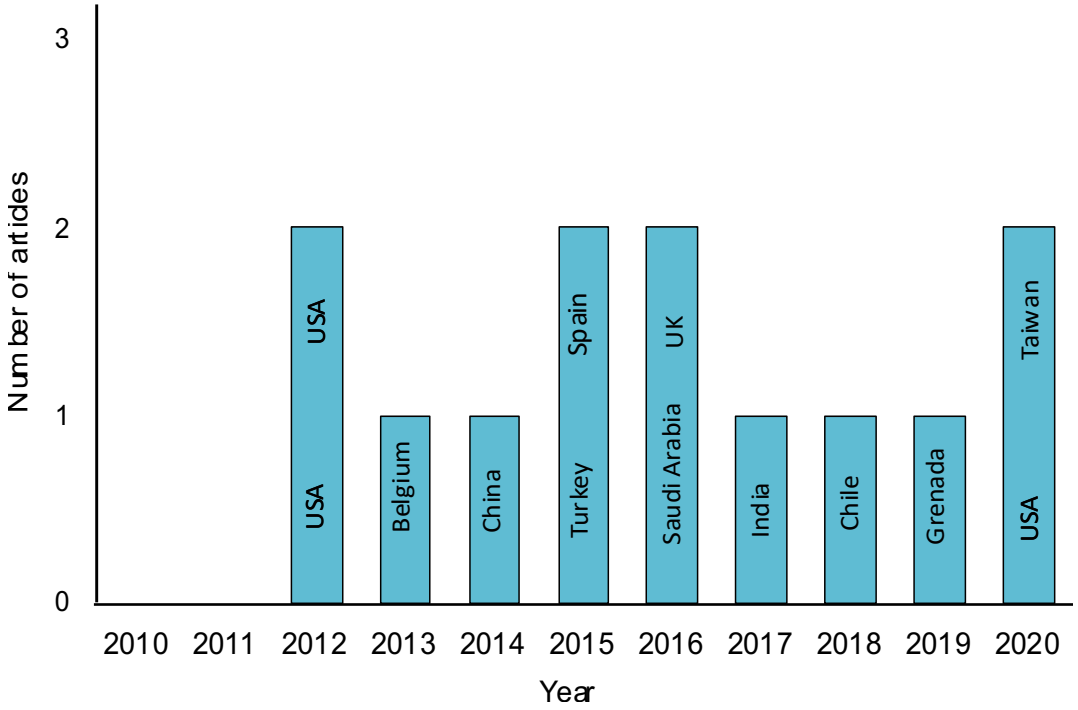
Note. Virtual microscope = VM; Light microscope = LM; Conventional microscope = CM

Population Demographic of the Studies

The population included in the studies comprises students of medicine (5 studies), dentistry (2 studies), medicine and dentistry combined (1 study), biomedical sciences (1 study), veterinary (2 studies), and medical laboratory sciences (2 studies). The population is from the United States, United Kingdom, Belgium, Chile, China, Grenada, India, Saudi Arabia, Spain, Taiwan, and Turkey. An overview of the year the article was published and the demographic distribution of the population is shown in Figure 2. Virtual microscopy was applied to teach general histology (4 studies), pathology (4 studies), both histology and pathology (1 study), cytology (1 study), dental histology (1 study), and hematology (2 studies).

Figure 2

Distribution of Articles Based on Year of Publication and Location of the Population



Effect of the Virtual Microscope on Student Performance

Assessing the differences between pre-test and post-test scores is frequently used to evaluate students' performance. Pre-test-post-test design involves collecting pre-test measures of the outcome of interest before administering some treatment, followed by a post-test on the same measure after treatment or intervention occurs. Pre-test–post-test designs can be applied in experimental and quasi-experimental educational research and used with or without control groups (Salkind, 2010). Mione et al. (2013) divided students into the light microscope and virtual microscope groups. The authors compared the differences in pre- and post-test scores between the groups. No significant differences were reported between pre-test and post-test scores among the student groups (2013).

On the other hand, Hande et al. (2017) divided students into three groups who were learning either with conventional microscopes (Group A), virtual microscopes (Group B), or both (Group C). Comparing the difference between pre-test and post-test scores among groups showed significant differences. Handle et al. discovered that the students who used both the light and virtual microscopes demonstrated the most significant improvement in their post-test scores compared to the pre-test, followed by the groups who used only virtual microscopes as their learning tool. The student group who used only conventional light microscopes showed the slightest difference between their pre- and post-test scores (2017).

Student performances in the formal academic examinations were also recorded to compare groups studying with conventional or virtual microscopes. Lee et al. (2020) divided students into two groups where one group used only light microscopes, and the other group used both light and virtual microscopes for learning histology and pathology. The group of students who used light and virtual microscopes performed better with less score variability on their laboratory examinations than the group who used only light microscopes. In a cross-over study, Nauhria et al. (2019) randomized participants either to the virtual microscopy or the light microscopy group then compared their mean scores in standardized exams. Students who used virtual microscopy scored significantly higher in the national board exam than those who used light microscopy. The authors also conducted pre- and post-test comparisons, where the students from the virtual microscopy group showed significant improvement in their post-test scores compared to the light microscopy group.

Ordi et al. (2015) used an online test to comparatively evaluate the skill acquired by two student groups. One group used light microscopes, and the other used virtual microscopes for learning pathology. The study found no significant differences in students' performance between the groups. Similarly, no significant differences were reported by Brueggeman et al. (2012) concerning group mean scores for the midterm laboratory exam, final laboratory exam, or the course total. However, in the study by Foad (2016), students from the virtual microscopy group performed better than those in the light microscopy group in practical and written exams. Compared to the conventional microscope group, students using virtual microscopes scored higher in multiple-choice questions, short essays, case analyses, and cognitive tests, which

measured their abilities to diagnose tissue structures from histological slides (Daniela et al., 2018; Tian et al., 2014).

In summary, 10 out of 12 studies found that students learning with virtual microscopes performed better in knowledge acquisition tests, including post-test, national board exam, online, written, multiple-choice, case analysis, and structure identification. The other two studies reported no significant differences in the mean score between groups using virtual or light microscopes (Table 3).

Impact of the Virtual Microscope on Long-Term Knowledge Retention

In a non-experimental comparative study, Solberg (2012) randomly assigned students in a clinical hematology course to use digital slides in virtual microscopes (Group 1) and traditional glass slides in the light microscope (Group 2). To evaluate students' immediate performance, separate microscope stations were set up where the students were asked to identify cellular structures. A delayed performance evaluation was conducted nine weeks after the initial laboratory sessions, similar to the immediate assessment. Students learning with the virtual microscope and digital slides (Group 1) performed better on evaluations immediately following the learning activity and after a considerable time (2012).

Student Preference and Satisfaction

Surveys based on the Likert scale were used to assess student preferences between virtual and conventional microscopes and their overall satisfaction with virtual microscopy and digital slides. In the study by Nauhria et al. (2019), 83% of the students preferred to use a virtual microscope over a light microscope. Student participants showed a high level of satisfaction and found virtual microscopes user-friendly and effective as teaching and learning tools (Daniela et al., 2018; Hande et al., 2017; Ordi et al., 2015; Sagol et al., 2015; Tian et al., 2014). The ability to view slides anywhere and at any time was considered highly advantageous by the participants (Brown et al., 2016; Ordi et al., 2015; Sagol et al., 2015).

Limitations

The goal of our scoping review was to investigate and synthesize a comparative overview of the impact of virtual and light microscopes as a teaching and learning tool for health science education. The eligible studies for our scoping review primarily evaluated student performance in knowledge tests and their satisfaction and preferences. We did not assess the quality of the studies included in our scoping review (Arksey et al., 2005). There is a clear need to conduct further studies to investigate the impact of virtual microscopy on other learning components, including engagement, knowledge retrieval, self-regulated learning, self-efficacy, and motivation. The findings of our review was based on the small number of articles that met our inclusion criteria specifically relevant to our research question. We acknowledge that negative results may have been missed due to publication bias.

Discussion

The use and popularity of virtual microscopes appear to be increasing worldwide across different disciplines of health science education. The vast majority of published literature on virtual microscopes focuses on the technical details of the technology and its sole effect on education. Our scoping review aimed to generate an overview comparing the impact of virtual and light microscopes in health professional education. We included comparative evaluation studies between student groups using conventional and virtual microscopes.

Based on our data extraction, we have summarized the effect of virtual microscopy on student performance, long-term knowledge retention, and satisfaction. The literature included comparative evaluations between groups of learners who used (i) only conventional microscopes, (ii) only virtual microscopes, and (iii) a combination of conventional microscopes. All the articles that assessed student satisfaction with virtual micoscopes reported it at a high level. Ten out of twelve studies reported higher test scores and better performance in knowledge acquisition by the student groups who used virtual microscopes alone or in combination with light microscopes. Two studies reported no significant differences between the light and virtual microscope users regarding group means for the midterm laboratory exam (Brueggeman et al., 2012) and online test (Ordi et al., 2015). These findings indicate that virtual microscopes have either equally good or better effects on students' knowledge acquisition or academic performance compared to light microscopes. In addition to the panning and zooming features, virtual microscopes also offer the ability to highlight areas of interest and create thumbnail views or location boxes for tracking navigation, which positively affects students learning. This technology can also potentially increase students' basic knowledge and problem-solving skills (Tian et al., 2014).

Only one study in our review collected test scores from participants who used virtual microscopes alone or virtual microscopes together with light microscopes (Hande et al., 2017). The study found that students who used both light and virtual microscopes performed significantly better than the group who used only a virtual microscope or only a light microscope as a learning tool. This performance indicates that virtual microscopes can augment traditional light microscopes in enhancing the learning experience and grasp of the subject (2017).

Only 13 studies fulfilled our selection criteria, suggesting that although there is widespread adoption of virtual microscopes as a teaching modality, there are not enough studies exploring the impact of this technology compared to light microscopes. The potential and benefits of virtual microscopes appear evident. However, further studies in this area can guide the best use of this technology to support and enhance active learning, engagement, professional development, problem-solving skills, and satisfaction.

Conclusion

Virtual microscopes are gaining popularity as a teaching tool for microanatomy and pathology. Reportedly, educational institutions are replacing traditional light microscopes with virtual systems to cope with increasing costs, space, and equipment. We conducted a scoping review to identify the relative effect of virtual and light microscopy on student performance, long-term knowledge retention, and satisfaction. All studies included in our review reported virtual microscopy as superior or equal to light microscopes in all aspects of students' learning experiences. Further studies in this area can guide educational institutions and educators to identify the best use of virtual microscopes as a teaching tool.

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Authors

Nazlee Sharmin is an Assistant Teaching Professor at the School of Dentistry at the University of Alberta in Canada. She completed her PhD in Physiology, Cell, and Developmental Biology and a MEd from the University of Alberta. Her research interest focuses on developing technologies in classroom teaching to improve students' learning experiences. *Email*: nazlee@ualberta.ca ORCID: https://orcid.org/0000-0002-2408-2333

Ava K. Chow is an Associate Professor at the School of Dentistry at the University of Alberta in Canada. She completed her PhD in Medical Sciences and a MEd from the University of Alberta. Her research interests include examining technology in education, foundational science education, and student-wellness. In lab, she studies the linkages between oral and systemic health. *Email*: akchow@ualberta.ca ORCID: https://orcid.org/0000-0002-1972-0310

Alice S. Dong has completed her Doctor of Dental Surgery from the School of Dentistry, University of Alberta in Canada. She is currently practicing as a general dentist. *Email*: sd5@ualberta.ca ORCID: https://orcid.org/0000-0002-2620-033X

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Text-to-Speech Software and Reading Comprehension: The Impact for Students with Learning Disabilities

Logiciel de synthèse vocale et compréhension de la lecture : l'impact pour les étudiants avec des troubles d'apprentissage

Sandra Raffoul, *University of Windsor*
Lindsey Jaber, *University of Windsor*

Abstract

This literature review examines the use of text-to-speech (TTS) software as an accommodation for students with learning disabilities and its impact on improving reading comprehension. As the development and availability of TTS tools and assistive technologies have increased over the past decade, it is significant to explore how they are used to accommodate students at all levels of education to promote a universal design of learning. Based on a review of the current literature and utilizing self-regulated learning theory as a framework, four significant themes have emerged: (a) TTS being seen as a compensatory tool; (b) improving reading abilities and comprehension; (c) increasing student motivation and self-efficacy; and (d) the need for training for students, educators, and parents. Findings of this literature review revealed that overall, TTS software is commonly used as a compensatory tool (mainly at the postsecondary level), has assisted in students improving reading speed, fluency, and content retention, resulted in increased student self-efficacy in reading abilities and independent learning, and that there is a significant need to allocate training and technological resources to support students. As there are various directions for future research, exploring this area can contribute to schools promoting inclusive and accommodating learning environments.

Keywords: text-to-speech; assistive technologies; learning disabilities; reading comprehension; universal design for learning

Résume

Cette revue de la littérature examine l'utilisation des logiciels de synthèse vocale (TTS, par ses sigles en anglais) comme mesure d'accommodement pour les étudiants ayant des troubles d'apprentissage et son impact sur l'amélioration de la compréhension de lecture. Alors que le

développement et la disponibilité des outils TTS et des technologies d'assistance ont augmenté au cours de la dernière décennie, il est important d'explorer comment ils sont utilisés pour accommoder les étudiants de tous les niveaux de l'éducation afin de promouvoir une conception universelle de l'apprentissage. À partir d'une analyse de la littérature actuelle et de l'utilisation de la théorie de l'apprentissage autorégulé comme cadre de référence, quatre thèmes importants ont émergé: a) le TTS étant considéré comme un outil compensatoire; b) amélioration des capacités de lecture et de compréhension; c) accroissement de la motivation et de l'auto-efficacité des étudiants; et d) le besoin d'une formation pour les étudiants, les éducateurs et les parents. Les résultats de cette revue de la littérature ont révélé que, dans l'ensemble, le logiciel TTS est couramment utilisé comme outil compensatoire (principalement au niveau postsecondaire), a aidé les étudiants à améliorer la vitesse de lecture, la fluidité et la rétention du contenu, a entraîné une augmentation de l'auto-efficacité des étudiants dans les capacités de lecture et l'apprentissage indépendant, et qu'il existe un besoin important d'allouer des ressources de formation et technologiques pour soutenir les étudiants. Comme il existe diverses orientations pour la recherche future, l'exploration de ce sujet peut contribuer à ce que les écoles favorisent des environnements d'apprentissage inclusifs et accommodants.

Mots-clés : synthèse vocale ; technologies d'assistance ; troubles d'apprentissage ; compréhension de lecture ; conception universelle de l'apprentissage

Introduction

Across education there is an aim to ensure that all students succeed academically and experience learning within an accessible and inclusive environment. Promoting inclusive education involves setting and supporting high standards for all students, including students with disabilities (Katz, 2013). Working within this environment can help students reach their learning goals as they move through different levels of schooling. One way in which schools and educational institutions can make learning accessible is to adopt a universal design for learning (UDL), which constitutes of a flexible and supportive instructional design for all learners, including those with learning disabilities, that is based on neuroscience and interpreted from an education perspective. This framework ensures that instructional goals, assessments, methods, and materials are usable and accessible by all (Hall et al., 2015). The main learning goals remain the same for all students, but the focus is on diversifying the ways that students learn and eventually reach these goals (Katz & Sokal, 2016). By implementing this framework into different areas such as lesson plans, assignments, and assessments, students can learn within an accessible environment that is accommodating to their learning needs.

Part of applying UDL is providing students with appropriate classroom and academic accommodations that can range from receiving extra time on assessments, extensions to complete class assignments, and accessing different forms of assistive technologies. As defined by the Individuals with Disabilities Education Act (IDEA), assistive technologies are "any item, piece of equipment, or product system, whether acquired commercially off the shelf, modified, or customized, that is used to increase, maintain or improve functional capabilities of a child with a disability" (U.S. Department of Education, 2019, IDEA Section 1401A). Some forms of assistive technologies include the use of word

processors, dictionaries, notetaking recorders, and different computer software such as text-to-speech (TTS). Due to the greater availability of computers and technological advancements over time, options for assistive technologies have proliferated in recent years (Perelmutter et al., 2017). In order for schools and educators to keep up with these changes, there is a need for increased research and training in assistive technology (Davis et al., 2013). With these increased options available, students can access a wider range of accommodations to best support their specific learning needs.

The incorporation of different forms of assistive technologies, such as TTS software, can impact how students with learning disabilities acquire, learn, and apply new knowledge. Text-to-speech software provides synthesized speech for a computer or other electronic device to read out the text for users experiencing reading difficulties (Perelmutter et al., 2017). As approximately 80% of students with learning disabilities exhibit difficulties in the area of reading (Cortiella & Horowitz, 2014), there is an essential need for using assistive technologies to support reading comprehension. As students with a reading disability often demonstrate considerable difficulty with accurate decoding and reading fluency, presenting reading material orally can remove the need to decode and potentially help students better comprehend written texts (Wood et al., 2018). Examining the use of TTS software to accommodate students can help to determine if TTS software is an appropriate accommodation to support reading comprehension. Using the framework of Barry Zimmerman's (1986) self-regulated learning theory, the current literature was reviewed to explore the question: What is the impact of text-to-speech software on supporting reading comprehension for students with learning disabilities?

Overview of Learning Disabilities and TTS Software

When researching the use of TTS software, it is important to first explore and define what learning disabilities are to be able to accurately assess its impact. In general, learning disabilities can be defined as:

> [A] variety of disorders that affect the acquisition, retention, understanding, organisation or use of verbal and/or non-verbal information. These disorders result from impairments in one or more psychological processes related to learning, in combination with otherwise average abilities essential for thinking and reasoning (Learning Disabilities Association of Ontario, 2015, Definition of Learning Disabilities section).

Learning disabilities can affect students within the classroom in different areas related to phonological processing, working memory, processing speed, language processing, visual-spatial processing, executive functions, and visual-motor processing (Learning Disabilities Association of Ontario, 2015). The implementation of TTS software is used to help students who may be experiencing a deficit in one or more of these areas. As students with learning disabilities are the highest group of students (approximately 35%) receiving special education services (Young et al., 2019), it is important to understand how assistive technologies support their learning needs.

The main function of TTS software according to Parr (2012) is to transform print texts of varying formats, such as books, magazines, newspapers, and websites so that they can be read aloud by

a computer-synthesized voice. This differs from a student having an accommodation that involves someone reading out loud to them with different tones and expressions. When using TTS software, students need to bring their own reading strategies to experience the text with the appropriate expression and intonation to make meaning (Parr, 2012). Features within TTS programs allow students to choose the options that best suit their learning needs. These features include different voices, reading rate, document tagging (which affects reading order), dynamic highlighting, translation, dictionaries, and the ability to create notes (Wood et al., 2018).

Some examples of commonly used forms of TTS software are Microsoft Word (Meyer & Bouck, 2014), Kurzweil3000 (Parr, 2012), Google Read&Write (Wood et al., 2018), and NaturalReader (Floyd & Judge, 2012). The availability and use of free or for-purchase TTS software has continued to increase over the past decade due to wide-spread technological advancements (Davis et al., 2013). Software that requires a paid license or subscription may include more advanced features. The increase in the types of TTS software also indicates an increase in accessibility as students can utilize it on different technological devices such as computers, smart phones, and tablets.

One of the main purposes of TTS software is that it decodes for the reader, which reduces the amount of attentional capacity needed to the individual letters and sounds, remembering the sounds, putting them together, and then comprehending the words and sentences (Parr, 2012). As previously noted, the struggle to decode text is a primary difficulty experienced by students with learning disabilities (Wood et al., 2015). To address this, TTS software may be used in different ways to support students' reading comprehension based on students' level of education. Floyd and Judge (2012) detailed how in elementary and secondary school settings, the focus is on accommodating and supporting students to better access learning materials, increase their engagement, and help them demonstrate their knowledge and understanding of the curriculum. Alternatively, at the postsecondary level, the focus is on providing reasonable accommodations during assessment. Whereas elementary-level students may use TTS software directly within the classroom to engage with the text and participate in reading-based activities, postsecondary students may only utilize TTS software outside of the classroom and during assessments.

What makes this review unique beyond other studies is that it explores the impact of TTS software on reading comprehension in addition to other external factors that are influential, such as the students' learning environment, self-efficacy, and how the technology is used by students, teachers, and parents.

Methodology

In order to accurately address and answer the guiding research question, relevant articles were selected based on specific inclusion and exclusion criteria that were defined prior to the search. Articles were located through Google Scholar, ERIC, Psych Info, and Omni Academic Search Tool which searches various databases such as EBSCO, ProQuest, Scholars Portal, JSTOR, and Oxford University Press. All combinations of the following terms were used to try to yield the most relevant results: 'text-

to-speech technology', 'text-to-speech AND learning disabilities', 'learning disabilities AND assistive technologies', 'text-to-speech AND reading comprehension'.

As the number of studies using TTS tools is increasing, especially within the past 10 years, this can be viewed as a reflection of the trend of wider access to improved TTS technology (Wood et al., 2018). Only articles published within the past 10 years were included in this review as the available technology prior to this period may not have served the same purposes or included the main features of TTS software. Only articles published within North America were included in this review as there is an aim to look at the specific use of TTS software at different levels of education which may not be standard across different geographical regions. As there are various forms of assistive technologies available within classrooms, the scope of this literature review was to specifically focus on TTS tools. Taking this into consideration, articles focusing on the impact of assistive technologies in general on students with learning disabilities were also included. Finally, articles with participants from elementary, secondary, and postsecondary levels of education were included to investigate if there are different uses and aims of the technology. After applying the specific inclusion and exclusion above, 11 peer-reviewed articles were selected for this literature review. The four themes detailed in this literature review were identified and coded as either being focused on the student, environment, or behaviour based on the theoretical framework outlined below.

Theoretical Framework: Self-Regulated Learning Theory

Many concepts presented within Zimmerman's (1986) self-regulated learning theory are relevant to the area of assistive technologies, particularly TTS software. Applying self-regulated learning theory provides a theoretical background to apply the significant themes that have been identified throughout the relevant literature in this area. Through the lens of self-regulated learning, students are viewed as metacognitively (planning, organizing, self-monitoring/evaluating, etc.), motivationally (perceiving oneself as competent), and behaviourally (selecting, structuring, and creating environments that optimize learning) active participants in their learning process. Each of these three domains can be connected to the area of TTS software and its impact on supporting reading comprehension. Metacognitively, students who use TTS software can be self-monitoring their learning as they progress through a text or complete an assessment. Students can work within the TTS software to organize their thoughts and learning through making notes and highlighting text. Motivationally, if students develop a higher sense of self-efficacy, their confidence and comfort with using the software could possibly impact reading comprehension. Behaviourally, students use TTS software as an accommodation to optimize and help structure their learning environment.

In order to attain their learning goals, students who are self-regulated learners self-generate different thoughts, feelings, and actions (Zimmerman & Schunk, 2001). According to Zimmerman (1989), the interactions of the person, environment, and behaviour can lead to the idea that "self-regulated learning occurs to the degree that a student can use personal (i.e., self-) processes to strategically regulate the behaviour and the immediate learning environment" (p. 330). Also, learners need to possess and/or develop supportive motivational beliefs in order to set challenging goals for

themselves and sustain self-regulatory efforts to achieve them (Zimmerman & Kitsantas, 2014). It is essential to consider the influence of and response to the students' physical environment in which they are using the software to help determine their development of self-regulated learning. As one of the principles of the UDL framework is to provide multiple means of representation (anticipating any physical, perceptual, and cognitive barriers that might interfere with student learning in advance) (Hall et al., 2015), exploring self-regulated learning theory can possibly help in the implementation of the framework.

Zimmerman's (2002) work also details the structure and function of self-regulatory processes in terms of three cyclical phases which include the forethought phase (task analysis and self-motivation beliefs), the performance phase (self-control and self-observation), and the self-reflection phase (self-judgement and self-reaction). As students use TTS software, they move through these three phases by self-regulating their actions, performance, and levels of self-efficacy. These all can contribute to the extent that a student is functioning as a self-regulated learner. As part of the learning environment, the TTS software can influence the student's strategic planning and confidence in their abilities.

Themes from the Literature

After reviewing the selected studies, four main themes emerged throughout the literature including: (a) its use as a compensatory tool; (b) improved reading abilities; (c) increased student motivation and self-efficacy; and (d) the need for training students, educators, and parents (Table 1).

Table 1

Selected Literature by Theme

Theme	Authors (year of publication)
TTS software as a compensatory tool	Floyd & Judge. (2012) Parr. (2012) Silvestri et al. (2021) Wood et al. (2018) Young et al. (2019)
Improved reading abilities	Floyd & Judge. (2012) Meyer & Bouck. (2014 Parr. (2012) Perelmutter et al. (2017) Stodden et al. (2012) Young et al. (2019)
Increased student motivation and self-efficacy	Brunow & Cullen. (2021) Parr. (2012) Young et al. (2019)

Theme	Authors (year of publication)
Training for students, educators, and parents	Davis et al. (2013) Perelmutter et al. (2017) Silvestri et al. (2021) Simmons & Carpenter. (2010) Young et al. (2019)

Text-to-Speech Software as a Compensatory Tool

A prominent theme throughout the literature is the concept that TTS software is seen, and primarily used, as a compensatory tool. When determining the impact and effectiveness of an assistive technology accommodation, such as TTS software, it is important to examine if the tool is compensating for a deficit or is an intervention for the long-term improvement of reading skills. Wood et al.'s (2018) meta-analysis examined the use of TTS and read-aloud tools for students with reading disabilities and emphasized how TTS and read-aloud tools can be used in both compensatory and intervention settings, though using it as an intervention is theoretically and practically different. For example, if a student is using TTS software as an exam accommodation, the tool here is compensatory as it assists the student in decoding and comprehending questions so that the student can provide assessment responses. Alternatively, if a student was using TTS software to read a text that contributes to the development of reading skills, the tool can be seen as an intervention where the student progresses over time. By having the ability to alter texts and self-monitor learning and progress by participating metacognitively (Zimmerman, 1986), TTS can also be used as a tool for intervention. Although the results of this meta-analysis may not be generalizable as it was noted that 22 studies were included, and the intensities of diverse TTS interventions were unable to be measured, there is mention of the need for more research to examine its effectiveness.

Young et al.'s (2019) quantitative study examined the effects of TTS on reading outcomes for students with learning disabilities at the secondary school level. Due to the small sample size of four students at the secondary level (three completing the study), results of this study may not be generalizable to the overall student population. The authors discussed how assistive technologies in general are used as compensatory tools that permit people to complete tasks that they would be unable to perform at the expected level without them. The sample for this specific study was ninth-grade students with learning disabilities; results showed that there was a functional relationship between the use of TTS and reading comprehension. Changes in the students' reading instruction (i.e., the use of TTS software) resulted in improvements to their reading comprehension. Oral reading fluency and speed increased for all participants as a result of using the TTS software. Of note was the finding that after consistent use of TTS, students eventually read and comprehended the material without the accommodation of the software. This suggests that although TTS is commonly referred to as a compensatory tool where teachers are able to work around a reading difficulty and remove the barrier of access, it can also be viewed as a remediation tool.

In an ethnographic study on the future of TTS technology, Parr (2012) discussed how TTS tools may "assist or segment task performance in some reading tasks, whereas in others they are used to compensate for, circumvent, or 'bypass' (not remediate) reading deficits (e.g., phonemic and phonic awareness)" (p. 1420). As data were collected through various forms such as participant observation, interviews, archival documents, photographs, and conversations, results may not be generalizable to students at different levels of education outside of this research setting. The study does contribute to the concept of TTS tools being used as a compensatory tool. Through bypassing, TTS technology is seen more as a compensatory tool because reading deficits are not being directly targeted for improvement but are instead being compensated for in that instance. Based on the results of the study, Parr (2012) stated that by discussing assistive technologies as compensatory supports, interventions, or bypass strategies, there is an assumption that there is a correct and proper way for students to read and access print. Challenging these uniform reading processes and strategies can help researchers and educators promote a UDL framework.

Results from Silvestri et al.'s (2021) quantitative study on the interaction of cognitive profiles and TTS software on reading comprehension of adolescents revealed that participants classified with more severe decoding deficits, in comparison to those with marginal deficits, benefitted more from the use of TTS software. The software was seen to compensate for word decoding without a redundancy effect with participant word decoding. It was also found that using TTS software alone is not enough to foster high-level text processing as there needs to be a combination of adequate knowledge of the text, text comprehension strategies, and word decoding skills that the TTS software enables. As the study included a sample size of 94 eighth-grade students, the results are generalizable to only upper elementary school students who are struggling with reading (Silvestri et al., 2021), which was noted as a limitation. This study highlights how the use of TTS software needs to be used in combination with various reading strategies and instruction.

As previously noted, the use and aims of TTS software can vary based on the level of education within which it is being implemented. Whereas there is a focus on developing and improving reading skills and comprehension at the elementary level, within postsecondary settings, TTS software is commonly used during assessments in a compensatory manner. Floyd and Judge's (2012) mixed-methods study on the efficacy of assistive technology on reading comprehension focused specifically on postsecondary students with learning disabilities. Results from the study showed an overall improvement in students' proofreading skills by demonstrating an increase in identification of errors when using TTS. By improving proofreading skills, the use of TTS software within this instance is intervention-based as the ability to identify errors can be a determinant of overall comprehension. Floyd and Judge detailed that overall, assistive technologies can be a viable support when completing reading comprehension tasks for students with learning disabilities at the postsecondary level. Noted as one of the limitations of this study, the ability to generalize the findings to a larger population can be due to the specific deficits and learner characteristics of the participants (Floyd & Judge, 2012). As most studies of TTS software have occurred at the elementary and secondary levels, more research is needed within postsecondary settings (Meyer & Bouck, 2014). Such research may lend support to

changing current practices of using TTS software solely as a compensatory support, and restructuring it as an intervention tool.

Overall, the theme of TTS software being viewed as a compensatory support is evident throughout the literature, but there are many emerging ideas indicating a possible shift to intervention. The need for more focus on TTS technology being used as an intervention is needed throughout each grade level as students learn and apply more complex reading strategies while they progress through their education. The degree to which it is used as an intervention may vary based on different factors such as the extent of teacher assistance to use the technology, the types of reading tasks or assessments, and the ability of the TTS software to track progress. TTS software being used and considered as a compensatory support aligns with concepts presented within self-regulated learning theory. As previously noted, the performance phase is one of three phases that structure self-regulatory learning processes and contains the two major classes of self-control and self-observation (Zimmerman, 2002). Within the class of self-control, students utilize aspects such as imagery and task strategies to facilitate learning. TTS software can be seen as aiding these processes as students can use different features within the software such as annotating, highlighting, and adjusting reading speed to help progress reading comprehension. Within the class of self-observation, students self-record and self-experiment to track their personal progress. The use of TTS software aids this process in allowing the student to independently work with the text. Whether the software is being used for the purpose of intervention or as a compensatory tool, processes within self-regulated learning theory highlight how the technology can be a significant influence in students developing into self-regulated learners.

Improved Reading Abilities

A second theme that is evident throughout the literature is that the use of TTS software can contribute to students' improved reading abilities including comprehension, reading speed, and fluency. Though the results of many studies have shown overall improvements in reading comprehension as a result of TTS accommodations, the baseline or preliminary reading skill levels of participants may have impacted the results. Sampling for these studies is important to consider as not all students have the same baseline reading skills prior to participating in the study. Similarly, Perelmutter et al. (2017) argued that reading comprehension measures should be included with outcome measures and the extent of improvements should then be correlated with baseline performances. As students with the most severe reading challenges have typically tended to make the most gains in comprehension when using TTS (Meyer & Bouck, 2014), assessing students at differing levels may reveal new insights into the impact of the technology.

Young et al.'s (2019) study on the effects of TTS on reading abilities for secondary students found an increase in comprehension of print material when using TTS and students reported that they remembered more information about the text after using the accommodation. Also, students with the lowest baseline comprehension scores showed the most improvement while using TTS software and maintained this improvement. This retention can translate into increased comprehension as students are able to show their understanding of the content. Young et al. noted that by alleviating the effort needed

to decode written text, students using TTS software can put more efforts into comprehension, which can lead to improved retention.

Parr (2012) examined the future of TTS technology in relation to reading instruction. They discussed how TTS software is not doing the work for students but rather it builds upon traditional reading strategies, such as word solving, expression, and fluency allowing for more advanced reading strategies including metacognitive strategies, student dialogue, and reader response. Results of the study indicated that the TTS software allowed students to activate metacognitive strategies before beginning a reading as they were able to choose the voice type and reading speed. During their second reading, interruptions to students' metacognitive processing and comprehension were prevented because they were able to utilize features such as pausing the reading to make connections. This suggests that providing students the opportunity and environment to access different metacognitive strategies can lead to improved reading skills and comprehension as a result of using TTS tools.

When focusing on the effectiveness of TTS software on reading comprehension for postsecondary students with learning disabilities, the results of Floyd and Judge's (2012) study showed that all participants, regardless of their reading ability, performed at a higher skill level when using TTS. Participants were better able to display their comprehension abilities with TTS as opposed to without it and were better able to recall information. This finding is consistent across studies and suggests that TTS improves students' memory and retention of content. Meyer and Bouck (2014) explored the impact of TTS on reading for adolescents with learning disabilities and found that there were no major improvements in actual reading fluency, comprehension, or task completion time. Although this result does not support the use of TTS as an intervention, all of the students believed that they read more fluently, comprehended more of the learning material, and overall spent less time on the reading task when using the TTS technology. As previously noted, TTS software removes the need for students to decode written text, so this can possibly remove some of the frustration that may arise when having trouble reading a text.

In Stodden et al.'s (2012) study of TTS software with secondary school students, they found that by eliminating the need for decoding, the TTS software provided students an opportunity to focus on the content, which lead to enhanced comprehension. The students' level of reading and vocabulary scores also significantly increased. Further, by being able to adjust the speed at which the software reads aloud the text, students customized their reading experience and learned at a pace that best supports their individual learning needs. The TTS software helped students learn the accurate and correct pronunciation of terms. Overall, the results of this study indicated increased comprehension and reading speed as a result of using the TTS software.

When reviewing the impact of TTS software on improving students' reading comprehension, the literature has revealed that overall, there are improvements as a result of using the software. As self-regulated learning theory refers to students as metacognitively active participants in their own learning process (Zimmerman, 1986), the use and effectiveness of TTS software is relevant as students use the technology to aid their learning. When students move through the forethought, performance, and self-reflection phases, they are tapping into a wide variety of strategies in order to progress to the next phase.

Common within the framework of self-regulated learning theory is the feature of the 'self-oriented feedback loop' which is a cyclical process in which students monitor the effectiveness of their learning strategies and respond to this feedback in different ways such as changing behaviours and/or replacing learning strategies (Zimmerman & Schunk, 2001). Some of these learning strategies can include environmental structuring, seeking information, goal setting and planning, keeping records and monitoring (Zimmerman, 1989), and can all be applied in some format while using TTS software. Notable aspects within the above studies included students increasing their reading speed, maintaining progress after using the software, increased memory/retention of content, alleviated frustration, and the ability to tap into metacognitive strategies. By using various self-regulated learning strategies and going through the 'feedback loop', students use the technology to help aid their strategies and make adjustments as needed in order to promote increased reading comprehension.

Increased Student Motivation and Self-Efficacy

A third theme that emerged was the use of TTS software to promote increased student motivation and self-efficacy. By playing a role in alleviating some of the frustration of decoding and by allowing more room for comprehension, TTS software can contribute to students' self-confidence and self-efficacy as a reader (Parr, 2012). With the removal of this frustration, students are working within an environment that can result in more engagement and confidence in their reading abilities. Positive impacts within these areas can also possibly lead to improved levels of reading comprehension for students with learning disabilities. According to Young et al. (2019), students who use TTS understand the text better, achieve at a higher rate, and are more likely to be engaged in their learning. When focusing on student engagement with reading, it is important to consider the student's current level of reading skills. If a student struggles with aspects of reading, such as comprehension and decoding, they may have low self-efficacy or not feel motivated to engage with the text. Disengaging from the act of reading at the elementary level can have an impact on students' progress as they are initially developing reading skills and strategies.

Parr (2012) noted that it is important to "prevent the vicious cycle of withdrawal from text, lower levels of motivation, lack of confidence, and inaccessible curricula, particularly in higher grades where there is a greater emphasis on accessing content through print text" (p. 1421). This is especially important at the secondary and postsecondary level where students need to read and complete course requirements independently and outside the classroom. Parr also claimed that when students are involved and engaged in decision-making regarding TTS tools, the technology becomes a support for self-efficacy and self-advocacy. By having the chance to utilize different features within the TTS software and customize it to their learning, students can gain more independence in their learning process. When educators use TTS software as part of a comprehensive approach to instruction, it decreases the need for human supports and increases independence, self-confidence, motivation, and accessibility of grade-level curriculum. By providing the accommodation of TTS software for students with learning disabilities, this can provide differentiation in learning, increase students' independence, and motivate students to read (Meyer & Bouck, 2014). A student's overall attitude and feelings towards reading is important in maintaining engagement, and seeing positive results with the TTS software can lead to increased confidence.

It is also important to consider the impact of the use of TTS software within a students' social environment. Students who use TTS tools, or any type of assistive technology, may be subject to stigmatization. A student with a TTS accommodation may be viewed negatively by their peers as they may not fully understand the purpose and need for different accommodations to support a disability. There may be the perception by classmates that a student using TTS tools is at an advantage in completing assignments and assessments compared to the rest of the class, or that they are privileged or cheating, and this can result in the student being stigmatized (Parr, 2012). Using TTS software during lessons or assessments typically requires the student to wear headphones. Wearing headphones has the potential to change the natural class dialogue that occurs around reading books, such as through reading circles, and collaborative activities centred around the text (Parr, 2012). Taking part in reading-based activities with classmates can help students engage more with the text, develop interest in the content, and gain new insights. With the use of a TTS software, this may potentially isolate the student from peer activities and impact class participation when wearing headphones. Through the above details, the impact of using TTS software on students' social environment, the increased use of online learning, and assessments may potentially reduce this impact.

In applying self-regulated learning theory to the above, we see how students' initial levels of self-efficacy within the forethought phase impacts self-regulated learning strategies and performance in the subsequent phases (Zimmerman, 2002). Low self-efficacy within the forethought phase can potentially impact performance and self-reflection after completing a reading task. High levels of self-efficacy can be seen to promote the use of effective strategies to become a self-regulated learner. In reference to the feedback loop, students' use of learning strategies and self-monitoring have been found to be related to students' self-efficacy perceptions, where higher self-efficacy is linked with the use of better-quality learning strategies (Zimmerman, 1989). As noted above, TTS software provides students with levels of autonomy and independence in their learning, which can contribute to feelings of self-efficacy. This autonomy can possibly provide students with an environment in which they can utilize effective learning strategies in order to improve reading comprehension skills. Self-regulation theory also considers the whole learning process in terms of motivation and helps students arrive at why they are completing a task in a purposeful role (Luo et al., 2021). Overall, the literature reveals that the use of TTS software as an accommodation can positively impact students' motivation, self-efficacy, and engagement with reading. In terms of possible stigmatization from using TTS tools, the increased opportunity to use TTS software across different technological devices and in environments outside the classroom can lead to decreased stigma for students with learning disabilities in both academic and real-world situations (Brunow & Cullen, 2021). The use of the technology can provide students with an environment in which they can become more independent in their learning and have an active role in customizing their learning experience.

Training for Students, Educators, and Parents

The final theme is the need for students, educators, and parents to receive training in TTS software and assistive technologies. Though students may have greater access to different forms of TTS software through the use of mobile devices and laptops, schools have existing initiatives and technology access gaps (Brunow & Cullen, 2021). Effective communication and collaboration between

school administrators, parents, teachers, and students regarding the selection and use of TTS software is essential to students' success at school (Parr, 2012). Challenging the notion that there is one standard way of teaching and learning helps promote a UDL framework within schools. By incorporating the use of assistive technologies as part of academic and classroom accommodations, students are shown that there are different approaches to learning the same content.

Perelmutter et al.'s (2017) study on assistive technology interventions for adolescents with learning disabilities highlighted the effectiveness of assistive technologies; however, the authors emphasized that they need to be specifically customized to the student using it, and consistent technical support needs to be available. Providing a student with the wrong form of assistive technology for their specific learning needs can be detrimental to their learning progress. This can possibly lead to students disengaging from the learning environment and not being appropriately accommodated. The study revealed that students had negative emotions connected to being frustrated with technological aspects and this resulted in altered perspectives of using the technology. It was also noted that some forms of assistive technologies can be harmful to students with learning disabilities, such as synchronous online course requirements that involve rapid reading and writing. This supports the idea that accommodations vary by student and there is not a standard form of assistive technology that can be used for all students with learning disabilities.

When focusing on which form of assistive technology is needed for a student, Simmons and Carpenter (2010) stated that it is the responsibility of the team that develops the student's individual education plan (IEP). The IEP team includes the student, parent, teachers, and additional educational administrators to help determine what academic and classroom accommodations are needed to best support the student. Failure to create an effective IEP, identify the appropriate assistive technologies required, and provide technological supports needed can result in assistive technology abandonment. Providing the necessary technological accommodations such as TTS software is essential, but it is just as significant to also provide sufficient training and resources to utilize the technology to its full capability. This training needs to be provided to everyone. For example, if the student will be utilizing the technology at home, parents require training in order to support the student while they are completing homework.

Similarly, Davis et al. (2013) emphasized that the decision-making responsibility about appropriate assistive technology must be shared among multiple individuals and that there are many factors that influence the selection of specific assistive technologies. In order to access and provide sufficient assistive technology devices, appropriate funding and resources need to be allocated towards schools and students with disabilities. Another factor to strongly consider when looking at the need for training is the impact of socioeconomic status on students' and schools' ability to access funding, devices, training, and necessary maintenance and supports. This study also noted a potential lack of expertise and training among members on the decision-making team and school professionals.

Young et al.'s (2019) study on the effects of TTS on reading for secondary students with learning disabilities found that although teachers see the benefit of assistive technology for students, the teachers did not often know how to effectively implement assistive technology in the classroom, and noted difficulties with obtaining devices for students. Even as TTS is becoming more accessible,

the use of it is not increasing overall throughout classrooms. As this study revealed that teachers perceived assistive technology to be used for a certain type of disability, this suggests that there is a lack of training about the purpose of these technologies and how accommodations are specifically designed for each student. The authors also noted the importance of students with learning disabilities learning how to use the technology to increase their acquisition of content and maximize understanding. Investing time and resources into training students on how to use the technology is vital. If students are not adequately trained, then they are not fully utilizing the software or properly learning the content. This is also significant based on the level of schooling. Students at the elementary level may need more support navigating technology whereas students at the secondary and postsecondary level may be able to troubleshoot or seek assistance on their own.

Silvestri et al.'s (2021) quantitative study on the interaction of cognitive profiles and TTS software on reading comprehension for adolescents found that teachers do not need extensive assistive technology training to support their students. Participants in the study learned and used only seven basic commands when using the Kurzweil software. Though there was an increase in level improvements of student reading comprehension, it is predicted that there can be even greater progress if teachers taught various reading strategies along with the use of the TTS software. Brunow and Cullen's (2021) quantitative study on TTS software and listening comprehension involved a teacher survey. Results revealed that even with the appropriate training, "TTS does not outweigh the need for an experienced teacher in the classroom to provide support and instruction to the students they serve" (p. 228). The current literature highlights the need for teacher training, but also emphasizes that TTS software does not substitute the need for instruction.

The learning environment in which students use the TTS software plays a significant role in self-regulated learning. A self-regulated learning perspective of students' learning and achievement has implications for the way teachers interact with students and the manner in which schools can be organized. There is a shift in focus from perceiving students' learning abilities and environments as fixed entities, towards students personally initiating processes and responses to improve their abilities and learning environment (Zimmerman, 1990). This notion also challenges the concept that there is a standard method of reading instruction and learning, thus promoting a UDL framework.

Directions for Future Research

After reviewing the literature and detailing the main themes, there are areas that can be identified as possible future directions for research. Though this paper is a literature review only, an avenue for future research could involve conducting a study with a qualitative or quantitative component to survey students regarding the use of TTS software. There is a clear lack of student voice in the existing literature. As such, qualitative research focusing on the experiences of students with learning disabilities and their use of TTS software is needed. By conducting qualitative interviews with students, researchers can gain deeper insight into students' thoughts and feelings towards using TTS tools as an accommodation. Interview responses could also help to better understand and address the possible social stigmatization that students can experience as a result of using TTS software. Further,

research into parent and educator perspectives and feelings towards assistive technologies, experiences with training, and how they perceive themselves to be supporting the student is also needed. It would also be beneficial to explore the possible barriers to accessing TTS software or assistive technology devices in general. Some of the barriers that could be examined include potential costs, allocation of school funding and resources, access to up-to-date technology, training opportunities, ongoing technical support, and device maintenance. These aspects would need to be considered alongside examining other factors, such as the socioeconomic status of the student population and school district.

Another area for further study is the investigation of different TTS software's ability to track reading skills to provide a clearer picture of changes in levels of reading comprehension. Wood et al. (2018) noted how some TTS programs such as Kurzweil 3000 can track and record user actions and that this data can be combined with students' type of disability and reading level to gain insight into how students are using the software. If program-generated data is found to be a viable source to further support students' learning with the software, then adequate training for educators is needed to obtain this data on a more regular basis. Overall, the above areas can provide potential directions to move forward within this area of study and identify strategies to better support students with learning disabilities.

Conclusion

Through the selection of relevant published studies and the identification of the four main themes (TTS software as a compensatory tool, improved reading abilities, increased student motivation, and self-efficacy and the need for training for students, educators, and parents), TTS software can be seen to have a positive impact on students with learning disabilities including increased motivation for reading and independence in learning (Meyer & Bouck, 2014). Through each presented theme, the role, use, and impact of TTS software is shown to vary based on the level of schooling. Being viewed as more compensatory at the postsecondary level and intervention-based at the elementary and secondary levels, the purposes and aims of TTS software can expand beyond preconceived notions of the accommodation and supports for students with learning disabilities. The literature also highlighted how TTS software can positively impact students' reading skills such as fluency, retention, and comprehension. By examining students' levels of motivation and self-efficacy, the impact of TTS tools on the student's social environment is also noted as a significant factor. Further, the need for training and technological resources is essential for the productive use of assistive technologies. The various works by Zimmerman (1986, 1989, 1990, 2001, 2002, 2014) on self-regulated learning emphasized how students are active participants in their learning and how the proper use of TTS software can aid students in becoming self-regulated learners within a UDL framework.

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Authors

Sandra Raffoul is a staff member at the University of Windsor in Ontario, Canada and a graduate of the Master of Education program. Having worked in accessibility services, she has gained experience facilitating the use of assistive technologies for assessments. Sandra is also a certified English language teacher specializing in adult education. *Email*: sraffoul@uwindsor.ca

Lindsey Jaber is an associate professor in the Faculty of Education at the University of Windsor in Ontario, Canada. She holds a Ph.D. in Educational Psychology from the University of Alberta. She is a registered Clinical, Counselling, and School Psychologist with the College of Psychologists of Ontario. Her professional and scholarly experience working in schools, community settings, and private practice has informed her research. *Email*: lindsey.jaber@uwindsor.ca

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Technology in Music Education

La technologie dans l'éducation musicale

Adita Maharaj, *The University of Trinidad and Tobago*
Akini Gill, *The University of Trinidad and Tobago*

Abstract

This study examined the use of music software as a pedagogical tool for the delivery of specific content in a music education course offered to Certificate and Bachelor of Education Program students at a Caribbean university. The existing course uses a traditional approach, and thus, the study is significant as the results would propel a shift toward transformational teaching. Twenty-four university students were chosen for the study which adopted a mixed methods approach. Over one semester, participants used a free, open-source music software program to learn simple time signatures. Students produced an assignment as well as completed a questionnaire. Ninety percent of students were able to compose eight bars of music according to a simple time signature using the software. Most participants intimated they felt comfortable and motivated using the software, they understood concepts taught, and they suggested its continued use. The majority of participants also stated that they required more training. Some participants even said that they would adopt this methodology on their teaching practicum. Based on the results, recommendations include the adoption of this and other technological teaching tools within the music program, a teaching practicum assessment, and a progressive training component for both students and staff.

Keywords: music education; technology; software; Caribbean

Résumé

Cette étude a examiné l'utilisation de logiciels de musique comme outil pédagogique pour la diffusion de contenu spécifique dans un cours d'éducation musicale offert aux étudiants du programme de certificat et de baccalauréat en éducation dans une université des Caraïbes. Le cours existant utilise une approche traditionnelle, et donc, l'étude est importante, car les résultats propulseraient un changement vers l'enseignement transformationnel. Vingt-quatre étudiants universitaires ont été sélectionnés pour l'étude qui a adopté une approche mixte. Pendant un semestre, les participants ont

utilisé un logiciel de musique gratuit et open source pour apprendre des indications de mesure simples. Les étudiants ont réalisé un travail et rempli un questionnaire. Quatre-vingt-dix pour cent des étudiants ont pu composer huit mesures de musique selon une indication de mesure simple à l'aide du logiciel. La plupart des participants ont indiqué qu'ils se sentaient à l'aise et motivés en utilisant lelogiciel, qu'ils comprenaient les concepts enseignés et qu'ils suggéraient de continuer à l'utiliser. La majorité des participants ont également déclaré qu'ils avaient besoin de plus de formation. Certains participants ont même déclaré qu'ils adopteraient cette méthodologie dans leur stage d'enseignement. Sur la base des résultats, les recommandations comprennent l'adoption de cet outil et d'autres outils d'enseignement technologiques au sein du programme de musique, une évaluation du stage d'enseignement et une composantede formation progressive pour les étudiants et le personnel.

Mots-clés : éducation musicale ; technologie ; logiciels ; Caraïbes

Introduction

The content of the general music education course offered at the Caribbean university can be described as an interactive exploration of a wide range of knowledge and skills in music required for the early childhood care and education and primary school settings. The purpose of the program is to explore resources and methods for using music as an intrinsic part of the education system. Thus far, the music course at the university has used a more traditional approach where students are exposed to lectures, discussions, and the playing of select instruments. Students use traditional modes of note taking and assessment and are accustomed to a bricks and mortar classroom. In education, however, there are different types of technological tools to support the creation of music through the use of technology. For example, there are different types of music notation software that can provide support to the pedagogical process.

The existing course also includes listening and appraisal of local, regional, and international music, making the distinction between training and teaching through music and special music education. The use of technology is limited to Canvas which is the learning management system (LMS) at the university. Students mostly access their reading materials and assignments from the LMS, but other than this, the use of technology as a methodological tool is not featured in the course. As faculty members of the university, we have noticed that there is a thrust to make the LMS more accessible to both students and lecturers. The university unit responsible for the LMS offers support by way of professional development sessions and support personnel, however, this has not yet caused any major shifts in the methodologies employed in this area.

Purpose

The purpose of this study was to explore the use of technology as a contemporary strategy in the existing music program at the university. Specific music content was chosen and relevant software used to deliver the content over a specified period of time. This was done with student teachers of the Certificate and Bachelor of Education programs. These programs were developed to train persons to

become teachers at either the early childhood or primary school level. The use of this software in music is a new methodology being introduced as part of the teaching of music content.

Significance

It is anticipated that use of the software can reveal definitive statements on the ease of integration, impact of use, and motivational factors displayed by both educator and students alike. Technology has been changing the way musicians produce and compose music and has also created more opportunities to enhance the teaching/learning process (Freedman, 2017). Marrying music and technology is a novel idea at this institution, and this research may propel changes in the program as we continuously seek tools for better teaching and learning as educators.

This research is also in keeping with the United Nations 2030 Sustainable Development Goal of quality education (UN DESA, 2023). As a publicly funded university, we must set the pace and tone for the introduction of innovative, novel ways of delivering content whilst engaging our clients. It is hoped that this research is one small step in that direction. On a larger scale, because the university is charged with the responsibility of teacher training to fulfil the needs of the nation's teaching service, this research is significant as it has the ability to impact the teaching methodology in future classrooms at both the early childhood and primary education level.

The international advent of COVID-19 has added another layer to the significance of this study. From spring 2020 to 2021, schools and other institutions of learning, from early childhood to university levels, have been adopting a blended learning approach to deliver content to students. It has become even more critical that budding teachers be equipped, especially at the level of the training institutions, to deliver content in the digital environment. This shift in learning and teaching is unprecedented, and research such as this is one small step toward achieving the goal of fully online teaching and learning and getting pre-service teachers accustomed to using technological tools.

Statement of the Problem

Since the inception of the music education program at the university, technology as part of the teaching/learning methodology has not been considered or adopted. This research introduces pre-service teachers in the primary and early childhood care and education specialization to the use of technology to learn specific music content. This opportunity may assist in marrying the traditional with the contemporary in teaching music content. In this highly technologically advancing age, the use of software to deliver musical content is relevant and may be valuable in achieving course goals.

Literature Review

Contemporary research advocates the critical significance of the use of music in early childhood classrooms. Music is a practice, and music education is the teaching and learning of music. Grounded in the theoretical underpinnings of constructivism, music has the unique ability to strengthen children's

cognitive, linguistic, physical, social, and emotional skills. Psychologist Howard Gardner has intimated that musical intelligence in young children has equal standing and should be given as much attention as the other intelligences (Gordon & Browne, 2017).

As far back as the 1950s, investigations have revealed the importance of music in early childhood development. Children express music in different ways than adults do as they use their senses from an early age to mimic the sounds they absorb in the environment. Critical to note also is the period from birth to the age of 6: this early childhood span is the window of opportunity for a child's musical development. It has been proven that very young children receive the tones of music and unintentionally differentiate in frequency, melody, and stimuli (Gordon, 2012). Important to note as well are the varied types of technological tools which exist now that support the creation of music. Focus can be placed on different types of music notation software available to educators, such as Finale and Sibelius, which propagate the integration of technology into education (Lam, 2023).

The Early Years

According to researchers, it is absolutely necessary that the early years of childhood are honed in order to facilitate learning so that children can unscramble the tones of music and build up a mental organisation system to memorise music (Feierabend, 2021). Children of this age develop musical skills through imitating and memorising rhythms and tones of songs through activities such as clapping to a beat and singing in tune. Developing musical skills is influenced by positive and negative factors. The school setting, in particular, must offer sufficient intentional, carefully articulated stimulation and exposure to music (Turner, 2008).

One may now ponder, "How can teachers of children effectively expose them to these skills?" In this technological world, it stands to reason that technology be used as a tool in music education. Further questions arise with respect to the teachers of young children. Are teachers trained to use these technological tools? Are training institutions integrating these methodologies within their programs? This research paper attempts to focus on the use of music software as part of a music course at a Caribbean university in order to gain insight into these questions. The use of music software will provide the opportunity to learn music theory through the making of music which may influence motivational factors. When teachers are motivated to teach, the benefits redound to the children in their care (Uludag & Satir, 2023).

Music Education Tools and Technology

Waddell and Williamon (2019) postulated that the overall evolution of music education tools and technology is indicative of a few major trends:

- Music technology has evolved in such a way that it has pushed music toward becoming shareable on a larger scale. This can be evidenced in music and education tools like Soundtrap or Google Classroom as well as broader multimedia social platforms like YouTube.

- Music education tools that offer additional practice to supplement classroom learning with specific skills are now available. These tools have paved the way for more self-paced learning and allow teachers to focus on other key skills.
- There are now newer media platforms, such as virtual reality and augmented reality, that showcase potential for enhancing learning both in and outside the classroom. This is done by enhancing collaboration or offering immersive ways of engaging visual learners. The usage of these in music education is currently limited, however, it is noteworthy, and major breakthroughs could spur innovations in the way teachers use media as a learning tool.
- Artificial intelligence applications may also act as a supplement to teaching and learning. One of the common areas is in aural skills training apps; digital assistants can provide assignments or offer feedback to students at lightning speed. Current usage is also limited but may offer opportunities for innovation as the technology matures.

Digital technology has become so interwoven with today's culture and society that it is difficult to imagine our everyday lives without it. So too, integrating these types of tools into music education may have invaluable effects, especially at the university level. This notion of the use of technology in music education programs is echoed by Parasiz (2018) who said that technology use in the field of music education has given a new perspective to the understanding of education. When the tools in music education are combined artfully with technology, this is powerful enough to provide an expanded education for music students and better equip them to enter the music world of the 21st century. In music education, thanks to technology applications, students are motivated and generally become more interested.

This, however, does not come without challenges. Gall (2013) examined the main inhibitors to trainee music teachers' use of technology within music classrooms. She discovered that a lack of computers and other equipment issues, and a lack of music staff sufficiently competent, confident, and/or interested in providing effective support were among the main challenges with respect to implementation. It must be noted that the role of the teacher has changed as traditional education methods, techniques, and applications have evolved, through research, to a more student-centered approach that requires techniques and applications conversant with the 21st century. Mouza and Lavigne (2012) also posited that teachers are no longer required to be the sole source of information but instead they guide students to access information and manage the learning process using digital tools. Educators at the university level must embrace this, as it has become an inevitable requirement that a teacher interested in guiding a student must be versed with technological developments in the field, as well as master and use the technology in the classroom and integrate it with pedagogical practice.

Objectives of the Study

The objectives of the study are:

1. To explore the use of music software as a novel strategy for delivering specific music content to pre-service teachers in a general music education course in the education department of this university.
2. To examine how pre-service teachers' performance and motivation are impacted by the use of music software.
3. To make practical recommendations based on the findings of the study regarding the implementation of music software in the general music education course at this university.

Research Questions

The following research questions have been identified for exploration:

1. Can music software be integrated in the general education program?
2. Do students comprehend music concepts and skills using the music software?
3. How is performance impacted with the use of music software?
4. Is the use of music software motivating for music education students?

Methodology

This study is mixed methods research and adopts a phenomenological approach. Vagle (2018) insinuated that this is a powerful research strategy that focuses on the study of an individual's lived experiences. It focuses on one basic common narrative experienced by a group of individuals. In this particular instance, the phenomenon being experienced is the use of technology in a program that did not contain this methodological strategy before. Some of the major advantages proposed by Vagle (2018) with this approach are:

- The production of rich data culled from individuals' experiences provides a context for a unique approach.
- A deep understanding emerges from individuals' experiences.
- Results contribute to new theories.
- Researchers can quickly adjust to new issues and ideas as they emerge.

Tashakkori and Teddlie (2010) indicated that a true mixed methods design includes a purposeful integration of qualitative and quantitative methods. This research adopts this integration which occurred at various stages of the research process. We further suggest that triangulation design involves a concurrent collection of quantitative and qualitative data with preferably equal priority being given to both sets of data. Drawing from this perspective, this research paper involved concurrent but

separate collection and analysis of qualitative and quantitative data. The data were merged or integrated in the analysis phase to draw conclusions. This approach allowed us to understand the statement of the problem in a holistic manner mitigating the disadvantages of a solely quantitative or qualitative study.

Participants

The participants included 24 (22 female and 2 male) students enrolled in the general music education course at the university. Fifteen participants were enrolled in the Bachelor of Education – Primary Education specialization, and nine participants were in Early Childhood Care and Education. They were all being trained to enter the teaching service in their specialization.

Data Collection

Questionnaire

Participants were asked to complete a questionnaire during a regular class session in the final week of the semester. This instrument was pilot tested prior to use to ensure reliability and consistency. Participation was voluntary. One of the researchers explained the purpose of the study. Participants willing to take part indicated their consent on a relevant form and filled out the questionnaire. To ensure anonymity, the participants did not indicate their names on the survey.

The questionnaire contained 10 items which assisted in answering the three research questions related to the integration of technology in the music course, comprehension of music skills, and student's motivation. The data collected from the questionnaire were entered and categorized using Microsoft Excel (2019, Microsoft 365) software. IBM SPSS Statistics (SPSS 08-1998) was used to analyze the data. Cronbach's alpha was computed using a data set of four items. The alpha coefficient for the items was 0.71 which suggests that the items have an acceptable internal consistency and, therefore, reliability.

Assignment

A music assignment was given during a regular face-to-face class session that required the use of music software in completing a task. The software chosen by the music teacher is called Sibelius; a music notation software that allows for composing, arranging, publishing, and teaching music writing and scoring. The study utilized the free trial version. The class was exposed to the music software over the duration of the course and were then administered a final assessment. One of the researchers explained the assignment in detail. The participants were required to compose eight bars of music in either 2/4-, 3/4-, or 4/4-time signatures. They were taught, over a 3-week period, how to compose bars of music in those time signatures, and they observed examples of composing in each of the time signatures using the software. For instance, the 4/4-time signature means four beats in each bar, which are note values used for writing music notation.

The assignment required participants to use the following seven note values in their eight bars of music:

- Semibreve or Whole Note = 4 beats
- Minim or Half Note = 2 beats
- Crochet or Quarter Note = 1 beat
- Quaver or Eighth Note = ½ beat
- Semiquaver or Sixteenth Note = ¼ beat
- Dotted Minim or Dotted Half Note = 3 beats
- Dotted Crochet or Dotted Quarter Note = 1½ beats

A timeframe of 2 weeks was given for completion of the assignment. The results from this assignment assisted in answering the research question related to how performance was impacted by the use of music software.

Results

Questionnaire

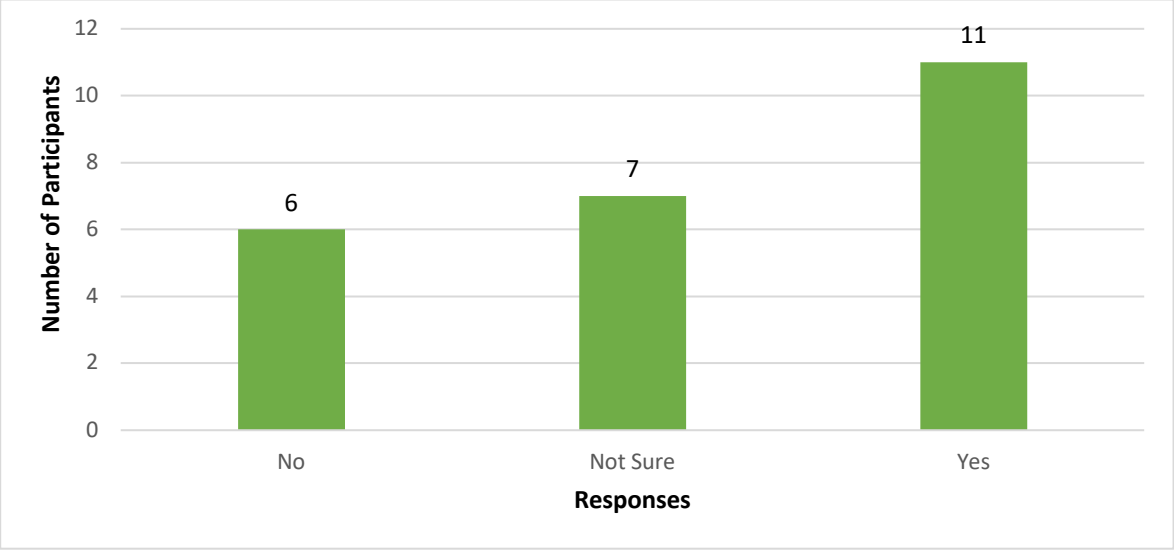
The participants were questioned about the overall rating of the general music education course. The majority gave the course a "very good" rating, 29% rated the course as "excellent," and 21% rated the course as "good." When questioned on the use of music software to create simple rhythmic bars, the majority of the participants' rating was "fair." Four participants rated the software as "excellent," three stated the music software was "very good," while four rated the software as "good." Only one participant rated the music software as "poor."

Participants were then asked if the use of the music software enhanced their understanding of the concept being taught. Six participants answered in the negative. However, the majority of participants (11) answered in the affirmative. Seven participants indicated they were "not sure" about the software enhancing their understanding of the concept being taught (Figure 1).

When questioned about the choice of a more traditional approach, the majority of participants stated that they preferred more traditional approaches to teaching music. Three of the participants were "not sure," while two stated they were unsure about how they felt. When participants were questioned about the instructor explaining the use of the software clearly, the majority found that the explanation by the instructor was "somewhat clear." Four participants stated that the explanation was "extremely clear" and eight participants indicated that it was "very clear." The least number of participants found that it was "not so clear."

Figure 1

Results of Survey Question on Whether Music Software Enhanced Conceptual Understanding



Note. $N = 24$.

Participants were subsequently questioned about their comfort level using the music software. Half indicated they were either very or somewhat comfortable using the music software (Table 1).

Table 1

Results of Survey Question on Participant's Comfort Level With Music Software

Extremely comfortable		Very comfortable		Somewhat comfortable		Not so comfortable		Not at all comfortable	
n	%	*n*	%	*n*	%	*n*	%	*n*	%
4	17	8	33	6	25	4	17	2	8

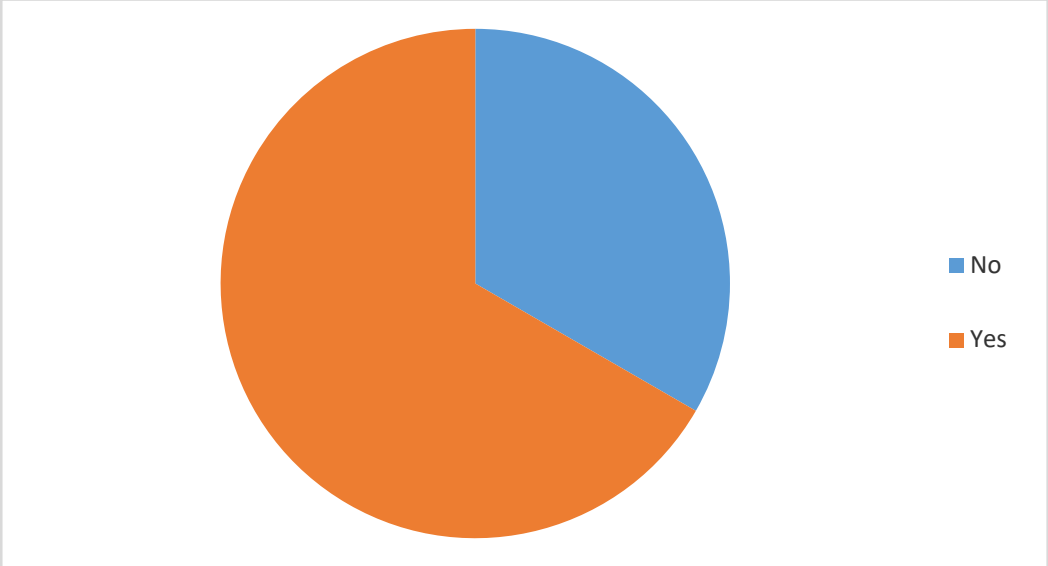
Note. $N = 24$.

Regarding whether they were motivated to complete the assignment using the software, the majority of participants indicated the "neutral" option whilst there were negligible differences for the "yes" and "no" options. As illustrated in Figure 2, 67% of participants suggested the continued use of technology as part of the music program at the university. However, a significant minority indicated they preferred the traditional approach.

Students undertake a teaching practicum in public schools every year where they are given the opportunity to apply the techniques learnt in training in the field with children at their assigned schools. Half the participants stated they do not feel comfortable using the software in their practicum, while approximately 30% indicated they felt comfortable and 20% said they were not sure.

Figure 2

Results of Survey Question on Continuing to Use Technology in the Music Course



Note. $N = 24$.

The survey culminated with a question on whether participants felt they required training to use technology in music education. Seventy-five percent of the participants answered in the affirmative and 25% felt they did not require any further training. The results reveal some simple yet compelling data which aided in answering the research questions related to integration, comprehension of music skills, and motivation. These will be explored in the Analysis and Discussion section.

The Assignment

As previously stated, participants were instructed to use the software to compose eight bars of music using specific time signatures. They were taught, step by step, how to use the software, completing examples both individually and in a group setting. All participants understood by answering questions in detail and were given individual attention where necessary. Instructions were given once per week over a 3-week period as part of the general music education course.

Participants completed the eight bars of music in an assigned time signature: 2/4, 3/4, or 4/4. Four participants did not submit their assignment. Twelve participants completed the assignment in the 4/4-time signature, six participants completed it in the 3/4-time signature, and two participants completed the assignment in the 2/4-time signature. The majority of participants used the note values semibreve, minim, crochet, quaver, and semiquaver. A minority of participants used the dotted crochet and dotted minim notes. Most participants were successful using the software in placing the number of beats required in each bar according to the given time signature. However, some participants had minor challenges putting the correct notes in each bar. Overall, the assignment was completed to a 90% accuracy.

Analysis and Discussion

The results yielded persuasive data that assisted in answering the research questions.

Research Question 1: Can Music Software be Integrated in the General Education Program?

Based on results from both the questionnaire and the assignment, the music software can be integrated into the music program. The fact that all participants were able to use the software to complete the assignment to a 90% accuracy suggests success. Also indicative of this is the fact that most participants understood the directions on the use of the software and were able to apply those instructions to complete the assignment. As previously stated, this music software was readily available online and came at no additional cost to the instructor or the university. This augers well for its continued use. Additionally, introduction of the software required no additional training for the instructor and no additional teaching time outside of the allotted 3-hour weekly slot assigned to the course. Overall, the results suggest a high success rate, but one can infer that some persons may have responded better to a different type of music software. This paves the way, in the future, for the music department to explore various types of similar software that offer a variety of methodologies in order to reach a more diverse student population.

Research Question 2: Do Students Comprehend Music Concepts and Skills Using the Music Software?

The successful completion of the assignment suggests that participants did indeed comprehend the music concepts and skills through the use of the music software. Additionally, the majority of students indicated on the questionnaire that the use of the software did indeed enhance their understanding of the concepts and skills taught. They were able to use the music software independently to complete the assignment which otherwise would have had to been taught using traditional modes. This brings the learner to the forefront of the teaching/learning process and re-engineers the role and responsibility of the teacher. Nart (2016) theorized that this type of approach is needed for the 21st century learner, especially in music education, where teachers guide the learning process and no longer control the information.

Research Question 3: How Is Performance Impacted With the Use of Music Software?

In the questionnaire, the majority of participants stated that the use of the music software enhanced their understanding of the concept being taught. This is evidence that their performance was positively impacted. This impact is further evidenced by the fact that the majority of students were able to complete the assignment with the use of the music software to a 90% accuracy. The methodology used, where step-by-step explanation of the content was done, questions were answered in detail, and individual attention given where necessary, reflects very positively on the use of the music software. Based on these findings, music software definitely impacts the performance of participants in a general music education course. Supporting these findings in the literature are Waddell and Williamon (2019)

who focused their research on the use of technology, especially in the music education classroom, and the role it plays in increasing the students' knowledge and skill sets.

Research Question 4: Is the Use of Music Software Motivating for Music Education Students?

Even though the results from the questionnaire revealed the majority of participants were "neutral" with respect to the motivational aspect of the use of the software, the completion of the assignment and the success rate suggest differently. Moreover, the fact that the majority of participants indicated they were "somewhat comfortable" using the software emphasizes that the use of music software is motivating for music education students. The motivation levels may be linked to the comfort levels of participants and the need for more training as they may require more exposure to this tool. As they experience continued success, motivation levels will, no doubt, increase.

Gall (2013) addressed inhibiting factors for the use of technology in music education. The research identified the teacher's role as one of guiding the process which entails the discovery of strategies for increasing the comfort levels of teacher trainees and ultimately increasing motivation. Data analysis has resulted in some definitive statements with respect to the research questions and given rise to recommendations for the university.

Recommendations

Our results have generated four recommendations.

1. Continued use of music software

The use of music software for music education students is an appropriate, introductory, contemporary strategy that can be used at the university level. As a first step of implementation, it should only be used for selected music content in the general music education course. Gradually, across semesters, the use of technological tools can be further added to the instructors' arsenal for teaching more music content.

2. Continued training

The majority of participants indicated a desire for more training. A progressive training program could form part of the general music program. Training can be tiered and involve experts in the field facilitating training for lecturers and, on another level, for students.

3. Introduction of technology in the practicum

The university can consider introducing an assessment in their practicum program that encourages the use of technological strategies in music with children in schools. Each practicum has a rubric that supervisors use for grading their students. On the present rubric, there is no set criteria for the use of technological tools. The administration and coordinators can include such criteria that will measure a teacher trainee's competence with respect to the use of technology in achieving learning outcomes in lessons.

4. Introduction of final assessments in music education that include technology

At present, there are no assignments in music that assess a student's use of technology as part of their training. The music department at the university can collaborate and amend the course outlines to include learning outcomes and assessments that target criteria related to a student's knowledge of the use of technology in music as well as competence with respect to the use of technology in teaching**.**

Conclusion

The purpose of this study was to explore the use of technology as a contemporary strategy in the existing music program at a Caribbean university. The results revealed that music software is relatively easy to integrate and has the ability to impact positively on student outcomes in music education. The university has its own responsibility with respect to ongoing research, development, and training of its personnel and music course offerings. However, technology has the potential to significantly impact the standards of the program.

As previously mentioned, the COVID-19 pandemic has propelled educators toward this paradigm shift where technology has become an integral aspect of teaching and learning. The traditional modes of transmission that still exist across our educational institutions may need to be revisited and can be supported by the relevant use of technology especially in hands-on areas such as music education. It is with the philosophy that one small step makes a difference that this research can be used as a benchmark by which other institutions and music instructors can bolster the delivery of content in order to enhance existing methodology. It is also anticipated that this study can contribute to further research and development on other innovative uses of technology for both general music education students as well as the wider student population.

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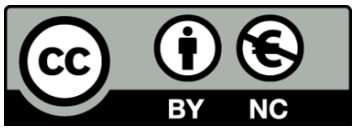
Authors

Adita Maharaj is an assistant professor at The University of Trinidad and Tobago and working in the field of education since 1991. Her main areas of research interests are early childhood, reading, curriculum facilitation, and technology inclusion. Her tertiary level experience began in 2010 at The University of the West Indies. *Email*: adita.maharaj@utt.edu.tt *ORCID:* https://orcid.org/0000-0002-2023-255X

Akini Gill is a music education instructor and lecturer in the Centre for Education at The University of Trinidad and Tobago for the past eight years. He is a strong advocate for resources to reach all students with learning disabilities and believes that all children can learn. *Email*: akini.gill@utt.edu.tt *ORCID:* https://orcid.org/0000-0003-4883-3178



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A Framework for Teaching Music Online. By Carol Johnson. Bloomsbury Academic. 199 Pages. ISBN HB: 978-1-3502-0186-6; ePDF: 978-1-3502-0185-9; eBook: 978-1-3502-0187-3

***Reviewed by Sandra Duggleby**, University of Calgary*

Introduction

In *A Framework for Teaching Music Online*, Carol Johnson formulates a clear and precise framework for teaching music online that is supported by 17 peer-reviewed articles she has authored on this topic. Well-known for her scholarship, Johnson's framework is designed to guide online teachers of music through a well-reasoned and logical step-by-step process using clear communication, authentic design, and quality assessment. The three-part process explores her framework starting with design and assessment of case studies. She then focuses on practical application of designing an online teaching space using technology tools and approaches as supporting learning mechanisms. In the final section of the framework, Johnson capitalizes on future innovations that delve into sharing knowledge and creating professional learning networks. The framework masterfully allows for discipline specificity in an arts-based discipline with niche areas such as music performance, theory, history, and composition. Johnson ensures that authentic supports are in place for all.

The Framework

There are three major components making up the framework, i.e., design, assessment, and communication. In Part I, *Exploring the Framework*, Johnson discusses the scaffolding approach, and supports it with figures for each step. She begins by focusing on communication, and elaborates on the importance of clarity of learning outcomes, timing, presence and community, and technology tools. Johnson brilliantly incorporates and supports Universal Design for Learning (UDL) in her framework so that instructors can ensure all diverse learners achieve success. Johnson (2022) confirms, "Through this simplistic description of complex design of strategic networks, recognition networks, and effective networks, UDL offers learners multiple ways to access online learning" (p. 70).

Designing lessons for student-centered learning is clearly articulated. Johnson ensures each process is supported with charts and figures that include organization, student well-being, planning, and accessibility. Case studies enhance the framework by demonstrating that the learning goals must also

meet the needs of the various diverse learners. The strategies in Johnson's framework for designing lessons for student success are supported by growth mindset as developed by the research of Carol Dweck. For real world learning experiences that are engaging, the constructivist theory is supported in her framework by Dewey, Piaget, and Vygotsky.

Johnson's framework also underscores the importance of assessment design that is authentic to the discipline. She describes in detail how assessment needs to be ongoing, throughout, and across the learning process. Case studies support her framework with real world scenarios about assessment that readers may find useful for developing similar online teaching scenarios. Assessment tools such as using video feedback provides students with their instructor's familiar face and with the appropriate tone of voice to ensure the students are on the right track and stay on the right track. Audio feedback is elaborated on as an effective way to provide assessment for learning. Due to her positive feedback on video and audio feedback, Johnson claims that one area for further research is "[t]o have future studies explore the efficacy of asynchronous video feedback for online music students" (p. 165).

In Part 2, *Practical Application,* Johnson explores considerations for teaching music online. Her framework supports instructors of all technology levels including those who are new to online teaching. For those who have experience teaching online, she provides additional aspects to consider. These additional aspects can be easily accessed in this book.

The well documented index clearly ensures smooth navigation to a multitude of practical charts, ideas, specific strategies, research, and theories for successful online teaching. The practicality of the framework brings research into the real world for authentic, everyday use. Not only is this framework valuable for the intended audience in the music discipline, it is a credible resource that has useful examples and resources for all instructors who are developing online courses.

Connection and Networking

In Part 3, *Future Innovations*, Johnson provides outstanding resources and networking connections to keep the audience informed about the most current upcoming innovations and research in technology for teaching music online. Detailed publications and authors who are experts in the field of teaching music online are easily accessed through Johnson's connection to her readers through her website. Each publication is easily accessed under the heading, with the topic from their current research.

Johnson emphasizes the importance of constructivist learning theory that supports the scholarship of using technology in the real world of teaching music online. One of this book's goals is to provide an easy-to-navigate framework throughout the online planning and teaching process. Johnson avoids a one-size-fits-all approach, and focuses on authenticity in her framework for real world, student-centered learning that includes diverse learners. Johnson provides a wealth of information to further promote networking where teachers can share new technology and learnings. "From this perspective, as we grow our expertise in online music learning, so too should we grow in our sharing and learning across our professional learning networks" (Johnson, 2022, p. 176).

Finally, the section on *Ways to Share Knowledge* is a practical component that provides peer-reviewed resources to answers to future questions. Johnson takes time to highlight the importance of sharing and contributing to the research of online music teaching. She outlines key scholars in this section who are renowned for their specialization in teaching music online. She has divided the easily accessible list of research fields into 11 categories ranging from online music technology teaching tools to online presence for ease of access and for further research. The book is intended to be a starting place for continued research on the topic, and support for, further research. Johnson encourages readers to take part in various forms of learning communities, as well as share their knowledge of online music teaching with colleagues and researchers.

Conclusion

The strength of this book aims to provide the reader with scaffolded steps for planning and developing online courses in music as well as other disciplines. It focuses on important points that are supported with charts and figures that are easily accessible. In addition to providing an outstanding framework for teaching online music, the book flawlessly provides the scaffolding for each step with detailed instructions supporting those new and not-so-new with opportunity to advance their online music teaching designs and activities. For easy access to specific topics, the index meticulously provides a straightforward and easy-to-navigate organized list of important points that are discussed in detail throughout the book. This framework can be used as a valuable handbook and guide to plan effective online courses in music and other disciplines.

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Author

Sandra Duggleby, PhD, is a field experience supervisor and sessional instructor at the University of Calgary in the Werklund School of Education in Alberta, Canada. Curriculum and instruction are her areas of specialisation. Dr. Duggleby has teaching experience in Alberta and Saskatchewan and has recently retired as a K–9 educator. *Email*: sduggleb@ucalgary.ca