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Blended Learning in Chemistry: A Systematic Review from 2010 to 2019

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Abstract

Blended learning in chemistry education issue has been discussed throughout the world over the past decade. The previous review on blended learning in chemistry provides valuable insight into learning strategies and specific courses (Nugraheni, Adita, & Srisawasdi, 2020). Nevertheless, that review did not pay attention to some issues in terms of authors' nationality, journals, research methods, research issue, education levels, online and offline learning portions, the specific model of blended learning in chemistry, and technology used in blended learning of chemistry. Hence, this study conducted a meta-review of 76 blended learning in chemistry research articles indexed by the SCOPUS database published from 2010 to 2019 to analyze these issues. The results revealed that blended learning in chemistry was implemented around the world. These findings showed that blended learning in chemistry was applied in the Americas, Europe, Asia, Australia, and South Africa. It was also found that most researchers employed a quantitative methodology such as experimental and survey. Meanwhile, most studies focused on the cognitive aspect, such as students' academic performance, students' metacognitive scaffolding, students' misconception, and students' retention. Furthermore, most of the blended learning was applied in higher education. The proportion of online learning and offline learning that is often done is half online and half offline. This research also found that flipped classroom is the most favorite model in blended learning with video as the primary technology used in blended learning in the chemistry classroom.

Keywords: Blended learning, hybrid learning, flipped learning, chemical education, meta-analysis

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Introduction

There is no doubt that the rapid growth of technology in this modern era opens up new opportunities in education. “Many studies revealed that the implementation of new educational models is more effective and preferred by students over traditional approaches” (Bernard, Bros, & Migdad-Mikuli, 2017, p.682). One of the new educational models that very popular is blended learning. Blended learning was created by educational policymakers and practitioners when merely online learning environments which had come with the enormous advancement of information and communication technology (ICT) did not stand the test of time by adopting the advantages and integrate them into physical environments (Seraji, Attaran, & Azizi, 2019).

In this 21st century, the advancement of blended learning has brought transformation to all subjects, including chemistry. Implementation of blended learning in chemistry courses is an astonishing issue. Many studies reported that blended learning could be a fruitful way to enhance teaching chemistry quality. For instance, Olakanmi (2016) reported that blended learning could facilitate students’ conceptual understanding of the rate of chemical reaction topics. Likewise, blended learning can foster students’ outcomes significantly (Bernard, Bros, & Migdad-Mikuli, 2017).

Although there have been numerous studies that discover the application of blended learning in chemistry, it is still needed to analyze the trends in the implementation of blended learning in chemistry. The previous study (Nugraheni, Adita, & Srisawasdi, 2020) reported a research trend focused on learning strategies and specific courses in chemistry. Regarding that results, some aspects still must be disclosed further, including authors’ nationality, journal, research methods and issue, education levels, online and offline learning portions, the specific model of blended learning, and technology used in blended learning of chemistry. The trends of these issues are beneficial to be the references for educators who want to practice blended learning, particularly in chemistry class. The literature on blended learning facilitated chemistry courses will be revealed in this study to understand the implementation and trend of blended learning in chemistry.

Research Question

There were seven research questions addressed as the following questions:

RQ1: What are the authors’ countries and journals of selected blended learning in chemistry studies?

RQ2: What are the research methods of selected blended learning in chemistry studies?

RQ3: What are the research issues of selected blended learning in chemistry studies?

RQ4: What are the education levels of selected blended learning in chemistry studies?

RQ5: What are the portions (online: offline) of selected blended learning in chemistry studies?

RQ6: What are the specific models of selected blended learning in chemistry studies?

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RQ7: What are the technologies of selected blended learning in chemistry studies?

Literature Review

Throne (2004) stated that blended learning is a learning model that portrays an opportunity to combine online instruction, bouncing innovative and contemporary technology, and traditional instruction bounces direct interaction and students' participation. In a broader sense to Thorne's idea, Bersin (2004) explained that blended learning is a model for a specific audience that integrates various training "media," such as technologies, activities, and events to create an effective training program. Meanwhile, Watson (2008) described that blended learning is a model that integrates face-to-face learning and online learning to foster the classroom experience and extend learning through the innovation of information and communications technology (ICT). Moreover, Graham (2006) described that blended learning is an integration of face-to-face learning with computer-mediated learning. In short, blended learning is an integration of online learning and face-to-face learning (Reay, 2001; Rooney, 2003; Sands, 2002; Ward & La Branche, 2003; Young, 2002). Blended learning is used interchangeably in the research literature as "personalized learning", "differentiated instruction", "hybrid learning", "technology-mediated instruction", "web-enhanced instruction", "mixed-mode instruction" (Krasulia, 2015). Furthermore, Staker & Horn (2012) described four models of blended learning (i.e., rotation model, flex model, self-blend model, and enriched-virtual model). In addition, the rotation model is divided into four sub-model: the station-rotation model, the lab-rotation model, the flipped-classroom model, and the individual-rotation model.

There have been numerous published studies on the implementation of blended learning in chemistry. For instance, blended learning was implemented in an organic chemistry course (Shattuck, 2016). The result indicated that blended learning intervention could promote students' achievement. Besides, blended learning was also implemented in the chemistry laboratory to optimize students' experience (Kennepohl, 2013). Moreover, blended learning was also applied in chemical information or cheminformatics (Baykoucheva, Houck, & White, 2015). The result revealed that students learned how to reach literature and chemical property more efficiently. Meanwhile, another study that implemented blended learning in chemistry pharmaceutical analysis (Visentin et al., 2013) was found that blended learning can foster students' involvement. Furthermore, the studies of Lee, Sharif, & Rahim (2018), and Jihad et al. (2018) also revealed that blended learning could enhance students' conceptual understanding.

Based on the literature review, researchers endeavor to applied blended learning to foster students' learning. It provides educators information on how to prepare appropriate learning activities for their students. To entitle the research and development of chemistry to become more knowledgeable, the previous implementation of blended learning has become pivotal to analyze.

Research Methodology

Resources

This research study analyzed papers from the SCOPUS database from 2010 to 2019 by searching for publications whose titles, abstracts, or keywords met the logical condition ('blended' or 'hybrid' or 'flipped') and ('learning') and ('chemistry') respectively. A total of 430 articles published in Scopus-indexed journals is appropriate for this review. In the final step, 76 papers were included in the present study. It was found by removing 138 non-article papers, four non-English papers, and 209 non-related papers (see Figure 1).

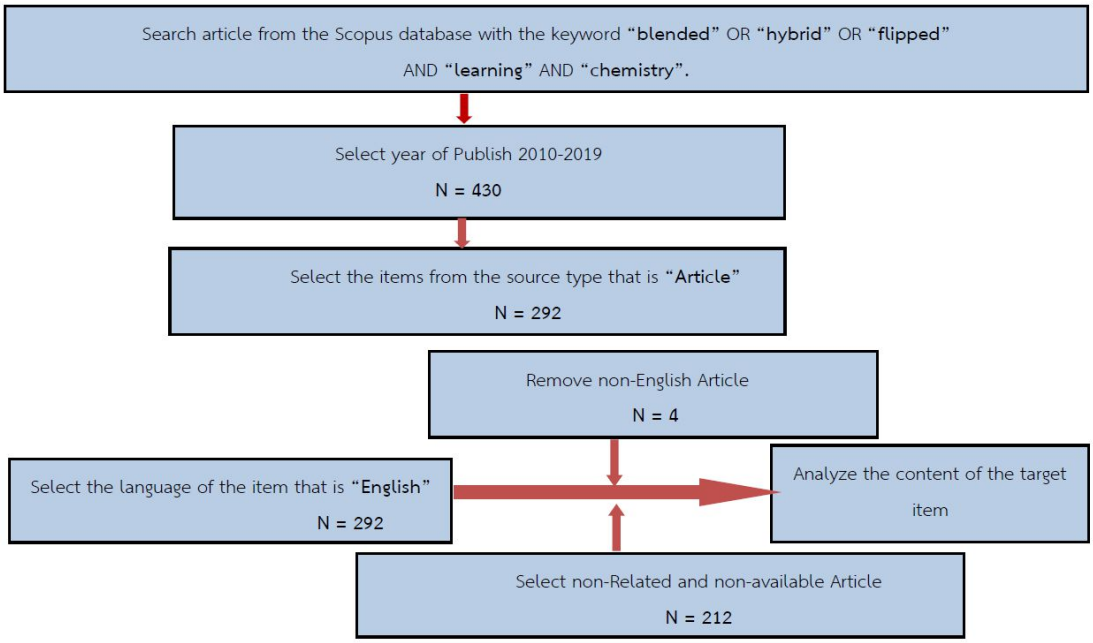

Figure 1. Scopus database searching steps.

Coding Scheme

In the present study, the aspects being analyzed include nationality of authors, journals, research methods, research issues, education level, the portion of online and offline learning, the specific model of blended learning, and technology used in blended learning of chemistry. Each dimension is described in the following item:

1) *Nationalities of authors and journals:* The standard information of those published papers is discussed, including authors' nationality and journals. The aim is to understand which countries are more often published papers on blended learning in chemical education.

2) *Research methods:* The category of research methods was based on the four standard research methods, consist of the quantitative research method, qualitative research method, mixed-method and

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system development.

3) *Research issues:* The research issues investigated in blended learning in chemistry education studies were also analyzed, including the aspects of cognition, affective, psychomotor, and social. According to the search result, it is divided into ten categories. The categories are cognitive, affective, psychomotor, social, cognitive-affective, cognitive-social, cognitive-affective-psychomotor, cognitive-affective-social, others, and non-specified.

4) *Education level:* This study classified the education level into four categories is Primary Education, Secondary Education, Higher Education, and Professional Development.

5) *Portion of online learning and offline learning:* This study also examined the portion of online learning and offline learning. According to the search result, it is divided into 20 categories, in percentage, as follows: non-specified; 10: 90; 13.33: 86.67; 15: 85; 20: 80; 25: 75; 28: 62; 30: 70; 33.33: 67.67; 35: 65; 40: 60; 47: 53; 50: 50; 57: 43; 60: 40; 62: 28; 66.67: 33.33; 70: 39; 80: 20.

6) *Specific models of blended learning*: According to Staker & Horn (2012), there are four major blended learning models. These are the rotation model, flex model, self-blend model, and enriched-virtual model. Furthermore, the rotation model has four sub-models: station-rotation model, lab-rotation model, flipped-classroom model, and individual-rotation model.

7) *The technology used*: The technology used is also investigated. According to the search result, it is divided into 14 categories. These are video, LMS/web, vodcast, go-pro, virtual laboratory, Television (TV), computer, mobile apps, simulation, LearnSmart Flash Card, lecture note, various ICT, specific technology, and non-specified.

■ Results

Nationalities of Authors and Journal

In this study, we merely probed the nationality of the corresponding author of the papers on blended learning in the field of chemistry. The results indicate that many countries have already tried to apply blended learning in chemistry teaching. The top country was the United States of America, with 48 papers. Furthermore, studies related to blended learning in chemistry were carried out in Canada with five papers, followed by Singapore with four papers and China with three papers. Also, figure 2 depicts that Colombia, Malaysia, Poland, and the UK contributed two papers for each country. Lastly, Australia, Belgium, Greece, Italy, Ireland, Russia, South Africa, and Turkey contributed one paper for each country. This result is quite similar to the previous study (Anthony et al., 2020), which revealed that the United States of America conducted many studies related to blended learning since most of the first researchers of blended learning adoption, such as Charles R. Graham, comes from the United State (US). These findings also suggested that blended learning in chemistry not only implemented in the Americas (US, Canada, Colombia) and Europe (Poland, UK, Belgium, Greece, Italy, Ireland, Russia) but also in Asia (Singapore, China, Malaysia, Turkey),

Australia and South Africa as well. Therefore, it implies that blended learning in chemistry is applied around the world.

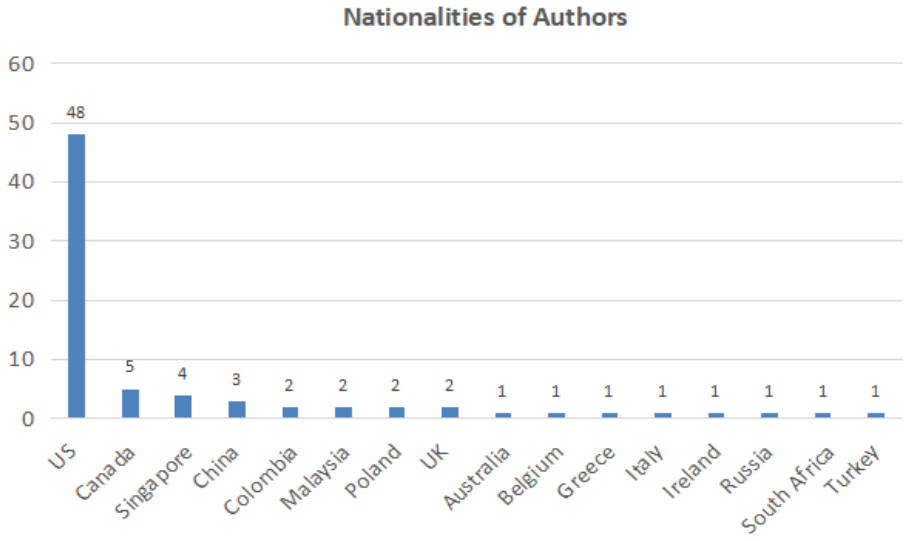

Figure 2. Countries publishing papers on blended learning in chemistry from 2010 to 2019

Figure 3 indicates that the top international reputable journal with the highest contribution in this field is the Journal of Chemical Education (JCE) with 35 papers, followed by the other reputable journals, Chemistry Education Research and Practice with 11 papers and ACS Symposium Series Journal with five papers respectively. Therefore, the other journals such as World Transactions on Engineering and Technology Education, Turkish Online Journal of Distance Education, International Review of Research in Open and Distance Learning contributed one paper for each journal. “The statistical finding of authors and journal titles could be a reasonable reference to researchers who intend to publish blended learning in the field of chemistry or host relevant workshop or conference in the future” (Premthaisong et al., 2019).

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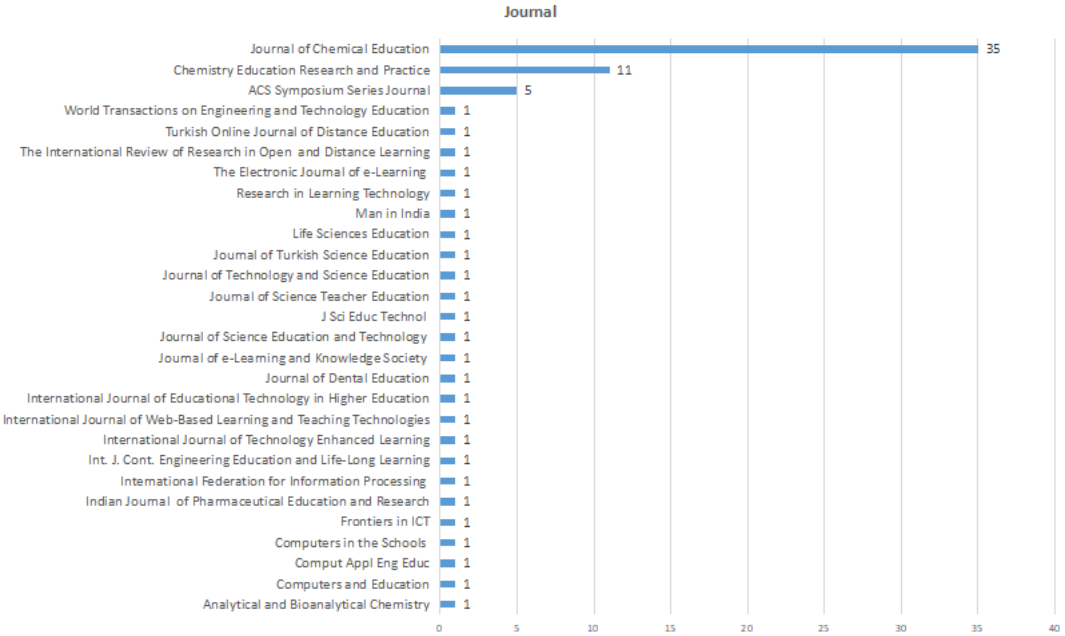

Figure 3. Journals publishing on blended learning in chemistry from 2010 to 2019

Research Method

The research method in each article was also investigated. Figure 4 describes the research method which is adopted in blended learning from 2010 to 2019. There were 56 pieces of research (73.68 %) adopting the quantitative method. Quantitative methods are divided into some methods further such as experimental and survey. One of the studies that implemented the quantitative method is the study by Canelas, Hill, and Novicki (2017). Pseudo-experimental was applied in this research. Another example implemented quantitative method is the study of Parsons (2019). The researcher employed a survey in his research.

Furthermore, nine pieces of research (N=9, 11.84%) employed mixed method, following by system development (N=8, 10.53%) and qualitative method (N=3, 1.32%), respectively. These findings are analogous with the prior review studies conducted by (Holton et al., 2006; Kumar and Pande, 2017; Anthony, 2020), who discussed those quantitative methods were the primary approach employed in previously blended learning studies. This finding also suggested that the implementation of blended learning in chemistry focused more on learning outcomes.

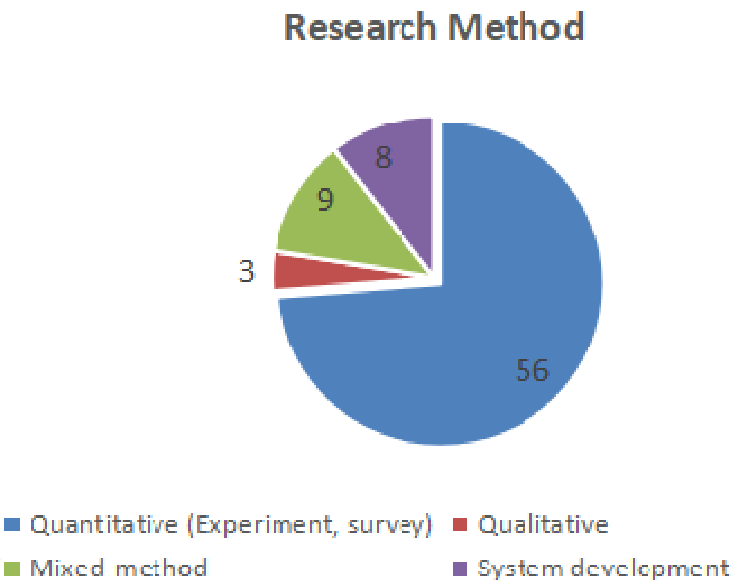

Figure 4. The research method adopted in blended learning in chemistry from 2010 to 2019

Research Issue

Research issues were probed in this study, including cognitive, affective, psychomotor, and social aspects. Even though some papers discuss the other aspects. Figure 5 depicts that cognitive aspects is the most popular issue in blended learning in chemistry (N=28, 36.84 %), followed by affective (N=16, 21.05 %), cognitive-affective (N=11, 14.47 %), cognitive-social (N=4, 5.26 %), psychomotor (N=3, 3.95 %) and non-specified aspects (N=3, 3.95 %) respectively. Non-specified means the papers did not mention the research issues. Furthermore, two papers (2.63 %) discuss other aspects, such as students' learning skills and learning efficiency. Lastly, there was one paper (1.32 %) that discuss the three aspects (cognitive, affective, psychomotor) and one paper (1.32 %) that discuss another three aspects (cognitive, affective, social). These findings indicate that blended learning in chemistry focuses more on investigating the cognitive aspect.

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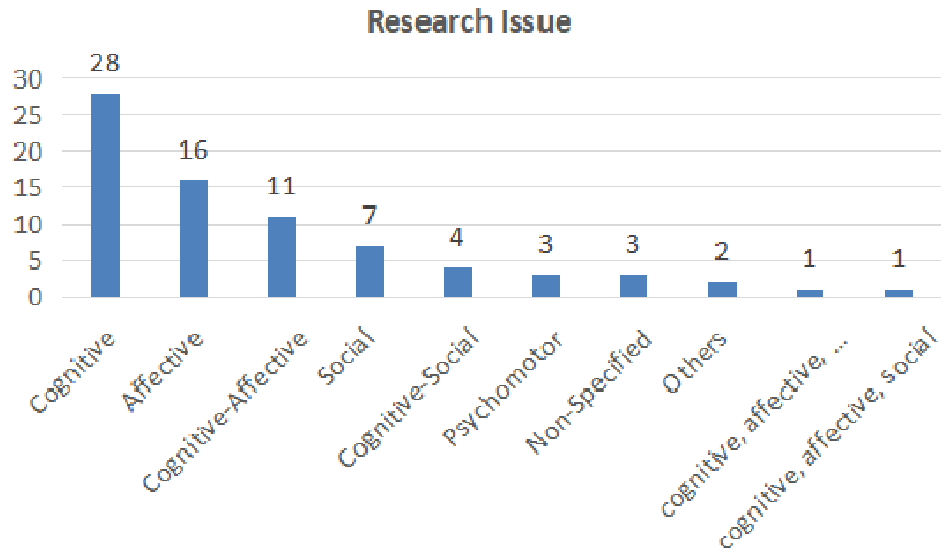

Figure 5. Research issues in blended learning in chemistry from 2010 to 2019

On the other hand, psychomotor was rarely investigated. Each aspect (cognitive, affective, psychomotor, and social) consists of some specific research issues. Table 1 shows some examples for each aspect. This specific research issue is in line with the prior study (Pima et al., 2018), which found that one of the hot themes in blended learning is learner performance with sub-theme performance outcomes, students' and teachers' satisfaction, engagement (students and teachers), students' retention, motivation and efforts, independence in learning, and learning autonomy.

Table 1

The Examples of Specific Research Issue for Each Aspect

Aspect	Specific Research Issue (s)	Example of Studies
Cognitive		Schultz et al.(2014)
		Butzler (2015)
		Weaver & Sturtevant (2015)
		Eichler & Peeples (2016)
		Mooring, Mitchell, & Burrows (2016)
	Students' academic performance/achievement	Shattuck (2016)
		Christiansen et al. (2017)
		Bernard, Bros, & Migdad-Mikuli (2017)
		Cormier & Voisard (2017)
		Halim et al. (2017)
		Ring (2017)
		Thomas (2017)

Aspect	Specific Research Issue (s)	Example of Studies
		Jihad et al. (2018)
		Lee, Sharif, & Rahim (2018)
		Lewis (2018)
		McDowell et al. (2019)
	Students' Metacognitive Scaffolding	Huertas et al. (2015)
		Casselman (2019)
	Students' Misconception	Fautch (2015)
	Students' Retention	Robert (2016)
		Ryan (2016)
Affective	Students' Engagement/Participation	Ozdilek (2013)
		Seery (2015)
		Legron-Rodriguez (2019)
		Stewart & Dake (2019)
	Students' Perception	Hanson (2014)
		Fitzgerald & Li (2015)
		Donnelly & Hernández (2018)
		Ping et al. (2018)
		Stewart & Dake (2019)
	Students' Attitude	Olakanmi (2017)
		Rau et al. (2017)
		Parsons (2019)
	Students' Motivation	Liu, Raker, & Lewis (2018)
	Students' Interest	Z. Liu, Lin, & Zhong (2019)
	Students' Independence	Butzler (2016)
	Students' Autonomous	Lenczewski (2016)
Psycho-motor	Students' Experimental/Research Skill	Brewer et al. (2013)
		Shen (2016)
		Bortnik et al. (2017)
Social	Students' Transferable Skill	Canelas, Hill, & Novicki (2017)
	Students' Collaboration Skill	Shattuck (2019)
Others	Students' Learning Style	Polizzi & Beratan (2015)
	Learning Efficiency	Zeng et al. (2018)

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Education Level

Education levels were examined, including primary education, secondary education, higher education, and professional development. As illustrated in figure 6, there were 67 studies (88.16 %) in higher education. At the level of higher education, blended learning usually implements at the undergraduate level. Therefore, the researches were implemented at the undergraduate level, such as Shattuck (2016), Fung (2017), Stewart & Dake (2019). Furthermore, there were five studies (6.58 %) conducted in secondary education. The studies were implemented in secondary education, such as Schultz et al. (2014) and Huertas et al. (2015). Meanwhile, three studies (3.94 %) implemented teacher professional development. The study of Clary (2017) invited in-service teachers as participants, while Tsoi (2010) and Ozdilek (2013) invited pre-service teachers as respondents. Lastly, another 1 study (1.32 %) was implemented in primary education (Shen, 2016).

The finding shows that higher education preferred to implement blended learning than the other levels, particularly in chemical education. It makes sense due to the character of learners. Graham (2006) stated that one of the major issues when implementing blended learning is the role of learner and self-regulation. Blended learning requires a large amount of self-discipline, particularly on the online learning part (Collis, Bruijstens, & Veen, 2003). College students are more independent than high school or primary school students. Hence, lecturers are easier to implement blended learning in higher education.

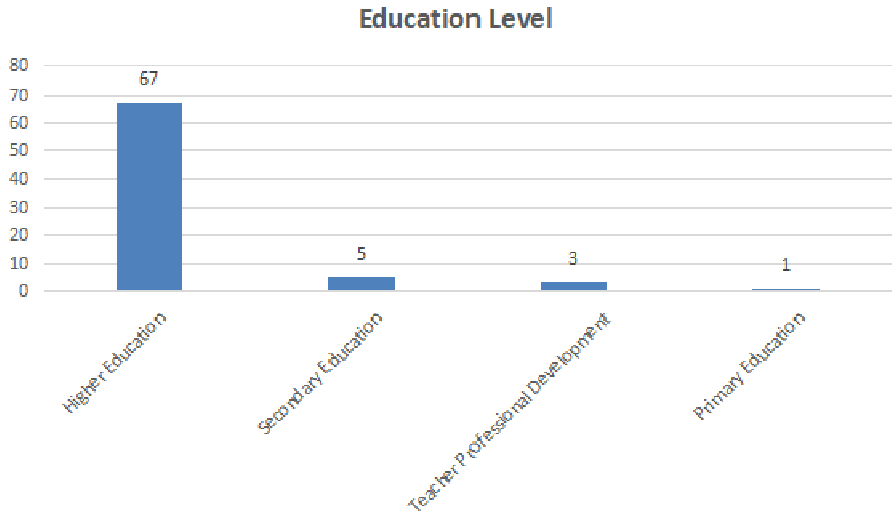

Figure 6. Education level applied blended learning in chemistry from 2010 to 2019

The portion of Online and Offline Learning

One thing that stands out in blended learning is the proportion of online and offline learning. In this study, the proportion was carefully investigated in terms of the percentage of the application. As illustrated in figure 7, 50:50 are in the highest ratio (N=13) after non-specified (not mentioned). It means

that the half-half proportion of online and offline learning is the most preferred by researchers. These findings are in line with the previous study (Pilcher, 2017, p.1696), which stated that “In many instances, the contact hour time in blended learning is split 50/50 between meeting in class and the online component”. It also makes sense since this portion is the easiest way among all portions. One of the studies that applied half/half proportion is Mcdowell et al. (2019). They implemented blended learning in their redesigned lecture with 2-section face-to-face instruction and 2-section online-mediated learning. The second rank of variation is 25:75 (N=6), followed by 33.33:67.67 (N=5). As a reference for this portion, the study of Shattuck (2016) applied a third of the course with flipped pedagogy. It refers to a third of the instruction is online, and the other part is offline. Furthermore, there are still many variations of proportion conducted by educators in chemistry class. Four papers explained 10:90 as the portion of their blended learning class. This proportion laid the least online learning than the other various proportions. One of the studies that applied this portion is the study of Stewart & Dake (2019). This study conducted 36 hours of in-class contact time with 15-20 minutes of online video per topic. Additionally, there were 12 topics in this study. It means roughly 480 minutes or 4 hours for online learning. The other (N=4) papers employed 70:30 as a proportion in their blended learning class. Furthermore, the ratio of 20:80 was used in the (N=3) papers. Meanwhile, 28: 62; 47:53; 57:43; 66.67: 33.33 and 80:20 were used in two papers (N=2). The ratio of 80:20 is the proportion that laid the highest online learning. The study by Hanson et al. (2014) used this proportion. Among ten weeks of instruction, educators conducted online learning in eight weeks and merely conducted offline instruction for two weeks. Kaur & Ahmed (2006), Kaur (2013), and Owston et al. (2019) recommended this portion as the successful delivery of blended learning by balancing 80% online learning (activities, information, resources, assessment, and feedback) and 20% classroom instruction (face to face). Likewise, Ginns & Ellis (2007) argued that achieving a blend of 29–30% face-to-face and 79–80% online teaching delivery is required for effective blended learning. This is in line with the previous studies (Graham et al., 2013; Bokolo Jr et al., 2020), which stated that one of the strategies to enhance the implementation of blended learning in higher education is making policies to decrease face to face classroom hours and increase online learning hours (Park et al. 2016). Lastly, 13.33:86.67; 15:85; 30:70; 40:60; 60:40; 62:28; and 67.5:32.5 were used in a study (N=1).

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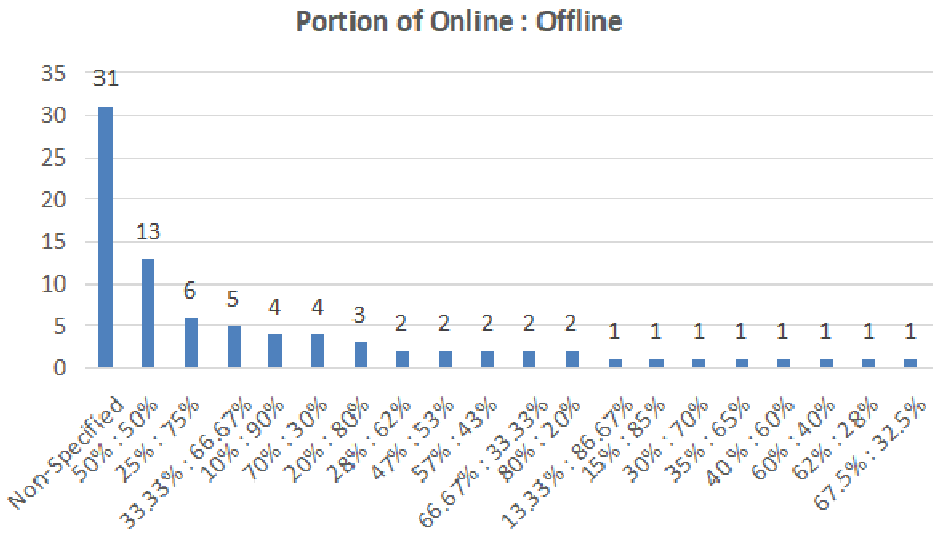

Figure 7. The portion of online: offline applied on blended learning in chemistry from 2010 to 2019

Specific Model of Blended Learning

Specific models of blended learning have also been investigating in this study. According to Staker & Horn (2012), there are four major blended learning models: rotation model, flex model, self-blend model, and enriched-virtual model. Furthermore, the rotation model has four sub-models: station-rotation model, lab-rotation model, flipped-classroom model, and individual-rotation model. Figure 8 indicates that the Flipped Classroom is the most favorite model in blended learning (N=50, 65.79%). For instance, the study of Shattuck (2016), Fung (2017), and Stewart & Dake (2019) applied flipped classrooms. It was followed by general blended learning (N=24, 31,58%). This category means the papers did not mention the specific model of blended learning. As references, Ping et al. (2018) and Shen (2016) implemented this model. Furthermore, another (N=1, 1.32%) study adopted a mixed model (blended learning in general and flipped-classroom). The study implemented this model is a study by Baepler, Walker, & Driessen (2014). Lastly, one research (1.32%) applied the rotation model (McDowell et al., 2019). This finding is in line with the prior study (Alammary, 2019), which stated that the flipped classroom is “the most widely known blended learning model." Likewise, Hwang, Lai, & Wang (2015) found that so many educators adopted flipped classrooms.

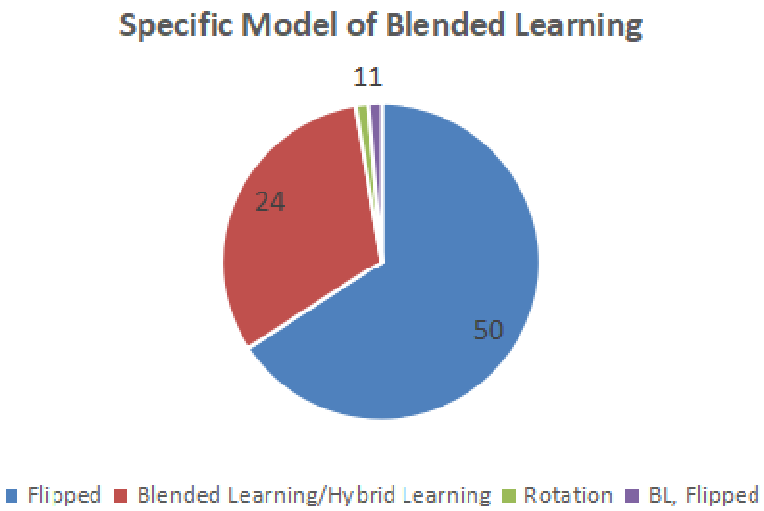

Figure 8. The specific model of blended learning in chemistry from 2010 to 2019

Technology

The technology used was also investigated. According to the search result, it is divided into 14 categories. These are video, LMS/website, vodcast, go-pro, virtual laboratory, Television (TV), computer, mobile apps, simulation, LearnSmart Flash Card, lecture note, various ICT, specific technology, and non-specified. Figure 9 depicts that video is the most popular technology in implementing blended learning in chemistry (N=34, 44.74%). The previous result revealed flipped classroom is the most popular model in blended learning since the video is the leading technology in the flipped classroom. The studies of Shattuck (2016), Fung (2017), and Stewart & Dake (2019) are some examples of using video as technology. Furthermore, another technology used was various ICT tools (N=17, 22.37%). One of the studies that using various ICT tools is the study of Shen (2016). The researcher used video and virtual laboratory in the classroom. Additionally, the other technologies used were various ICT tools were LMS/website (N=6, 7.89%), specific technology (e.g. Explain everything app, multitouch book, notebook (QDWD) (N=3, 3.95%), virtual laboratory (N=2, 2.63%), simulation (N=2,2.63%), vodcast (N=2, 2.63 %), go-pro (N=1, 1.32%), Television (TV) (N=1, 1.32%), Computer (N=1, 1.32%), mobile (N=1, 1.32%), Flashcard (N=1, 1.32%). Meanwhile, four studies (5.26%) did not mention the technology used in their blended chemistry classroom.

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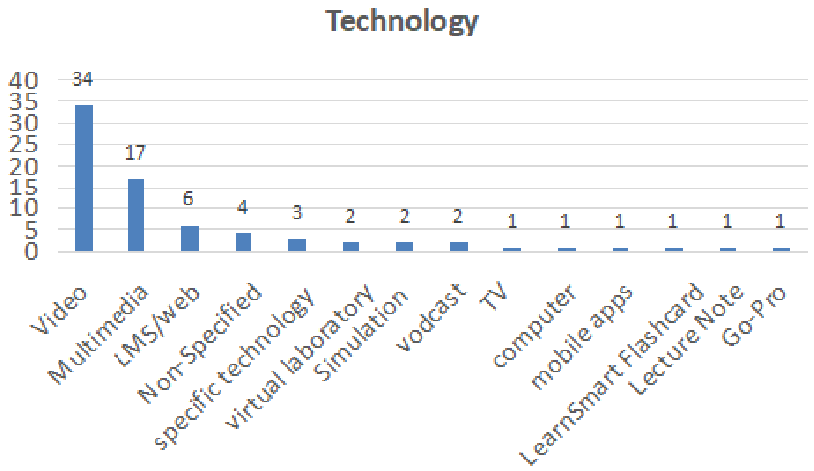

Figure 9. The technology used in blended learning in chemistry from 2010 to 2019.

Conclusion

This present study performed a meta-review and analysis of implementing blended learning in chemistry from 2010 to 2019. The findings revealed that blended learning in chemistry is widely implemented around the world. It also found that most researchers employed a quantitative methodology. It implies blended learning in chemistry focuses more on students' learning outcomes.

Meanwhile, the results also revealed that the issues related to "psychomotor" were rarely analyzed. Instead, most studies focused on the cognitive aspect. This finding shows that many studies are required to enhance students' academic performance. Furthermore, it implies that examining the impacts of blended learning in chemistry courses on students' cognitive aspects remains an exciting and prominent issue.

Furthermore, it also found that most studies have been conducted in higher education. It implies that lecturers preferred to conducting blended learning than teachers. It is also related to the character of the learner. The sophomores are usually more independent than high school students. Hence, lecturers are easier to implement blended learning in higher education.

Besides, this study also found in the portion of online instruction and offline instruction. Half online and half offline become favorite parts. Even though, there were many various portion such as 10% : 90%, 13.33% : 86.67%, 15% : 85%, 20% : 80% and many other portions. It implies that educators implemented blended learning in chemistry in many various portions. It depends on the characteristic of the learners and specific courses.

Therefore, this research also found that flipped classroom is the most favorite model in blended learning, particularly in the chemistry classroom. Lastly, the findings also found that video is the most popular technology in implementing blended learning in chemistry. The previous result revealed flipped

classroom is the most popular model in blended learning since the video is the leading technology in the flipped classroom.

Regarding the results, some points can highlight for future endeavors. The present study found that cognitive aspects are still to be a prominent issue. Meanwhile, most blended learning in chemistry was conducted in higher education with sophomores as participants. It implies that implementing blended learning in chemistry for the other education levels, including the public (citizen), is still required.

Additionally, the prior study results (Nugraheni, Adita, Srisawasdi, 2020) also highlighted some important points. These are blended learning in chemistry focuses more on supporting theoretical chemistry. Hence, the implementation of blended learning on application chemistry opens up an opportunity to be investigated. Furthermore, teamwork learning becomes the favorite learning strategy in the implementation of blended learning in chemistry. Regarding the findings of the prior and present studies, the implementation of blended learning on the application of chemistry (e.g., circular plastic economy) with public participation approach (e.g., citizen science and inquiry) is an exciting issue to be explored for future work.

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References

Alammary, A. (2019). Blended learning models for introductory programming courses: A systematic review. *Plos One*, *14*(9), e0221765. https://doi.org/10.1371/journal.pone.0221765

Anthony, B., Kamaludin, A., Romli, A., Raffei, A. F. M., Phon, D. N. A. L. E., Abdullah, A., & Ming, G. L. (2020). Blended learning adoption and implementation in higher education: A theoretical and systematic review. *Technology, Knowledge, and Learning*. https://doi.org/10.1007/s10758-020-09477-z

Baepler, P., Walker, J., & Driessen, M. (2014). It's not about seat time: Blending, flipping, and efficiency in active learning classrooms. *Computers & Education*, *78*, 227-236. https://doi.org/10.1016/j.compedu.2014.06.006

Baykoucheva, S., Houck, J. D., & White, N. (2015). Integration of endNote online in information literacy instruction designed for small and large chemistry courses. *Journal of Chemical Education, 93*(3), 470-476. doi:10.1021/acs.jchemed.5b00515

Bernard, P., Bro• , P., & Migdał-Mikuli, A. (2017). Influence of blended learning on outcomes of students attending a general chemistry course: Summary of a five-year-long study. *Chemistry Education Research and Practice, 18*(4), 682-690. doi:10.1039/c7rp00040e

Bersin, J. (2004). *The blended learning book: Best practices, proven methodologies, and lessons learned.* Pfeiffer: San Francisco

Bokolo, A., Kamaludin, A., Romli, A., Mat Raffei, A. F., A/L Eh Phon, D. N., Abdullah, A., Leong Ming, G., A. Shukor, N., Shukri Nordin, M., & Baba, S. (2019). A managerial perspective on institutions' administration readiness to diffuse blended learning in higher education: Concept and evidence. *Journal of Research on Technology in Education*, *52*(1), 37–64. https://doi.org/10.1080/15391523.2019.1675203

Bortnik, B., Stozhko, N., Pervukhina, I., Tchernysheva, A., & Belysheva, G. (2017). Effect of virtual analytical chemistry laboratory on enhancing student research skills and practices. *Research in Learning Technology*, *25*(0). https://doi.org/10.25304/rlt.v25.1968

Brewer, S. E., Cinel, B., Harrison, M., & Mohr, C. L. (2013). First-year chemistry laboratory courses for distance learners: Development and transfer credit acceptance. *The International Review of Research in Open and Distributed Learning*, *14*(3), 488-507. https://doi.org/10.19173/irrodl.v14i3.1446

Burchett, S., Hayes, J., Pfaff, A., Satterfield, E. T., Skyles, A., & Woelk, K. (2016). Piloting blended strategies to resolve laboratory capacity issues in a first-semester general chemistry course. *Journal of Chemical Education, 93*(7), 1217-1222. doi:10.1021/acs.jchemed.6b00078

Butzler, K. B. (2015). ConfChem conference on flipped classroom: Flipping at an open-enrollment college. *Journal of Chemical Education*, *92*(9), 1574–1576. https://doi.org/10.1021/ed500875n

Canelas, D. A., Hill, J. L., & Novicki, A. (2017). Cooperative learning in organic chemistry increases student assessment of learning gains in key transferable skills. *Chemistry Education Research and Practice*, *18*(3), 441–456. https://doi.org/10.1039/c7rp00014f

Casselman, M. D. (2019). Effective implementations of a partially flipped classroom for large-enrollment organic chemistry courses. *ACS Symposium Series Active Learning in Organic Chemistry: Implementation and Analysis,* 187-196. doi:10.1021/bk-2019-1336.ch011

Christiansen, M. A., Nadelson, L., Etchberger, L., Cuch, M., Kingsford, T. A., & Woodward, L. O. (2017). Flipped learning in synchronously-delivered, geographically-dispersed general chemistry classrooms. *Journal of Chemical Education*, *94*(5), 662–667. https://doi.org/10.1021/acs.jchemed.6b00763

Clary, R., Dunne, J., Elder, A., Saebo, S., Beard, D., & Wax, C. et al. (2017). Optimizing online content instruction for effective hybrid teacher professional development programs. *Journal Of Science Teacher Education*, *28*(6), 507-521. https://doi.org/10.1080/1046560x.2017.1379859

Collis, B., Bruijstens, H., & van der Veen, J. K. (2003). Course redesign for blended learning: Modern optics for technical professionals. *International Journal of Continuing Engineering Education and Lifelong Learning, 13*(1/2), 22–38.

Cormier, C., & Voisard, B. (2017). Flipped classroom in organic chemistry has significant effect on students' grades. *Frontiers in ICT*, *4*. https://doi.org/10.3389/fict.2017.00030

Debska, B., Guzowska-Swider, B., & Heclik, K. (2016). The benefits of using blended-learning methods in spectroscopy. *International Journal of Continuing Engineering Education and Life-Long Learning, 26*(2), 153-167. doi:10.1504/ijceell.2016.076012

Donnelly, J., & Hernández, F. E. (2018). Fusing a reversed and informal learning scheme and space: Student perceptions of active learning in physical chemistry. *Chemistry Education Research and Practice*, *19*(2), 520–532. https://doi.org/10.1039/c7rp00186j

Ealy, J. B. (2013). Development and implementation of a first-semester hybrid organic chemistry course: Yielding advantages for educators and students. *Journal of Chemical Education, 90*(3), 303-307. doi:10.1021/ed200858p

Eichler, J. F., & Peeples, J. (2016). Flipped classroom modules for large enrollment general chemistry courses: a low barrier approach to increase active learning and improve student grades. *Chemistry Education Research and Practice*, *17*(1), 197–208. https://doi.org/10.1039/c5rp00159e

Enneking, K. M., Breitenstein, G. R., Coleman, A. F., Reeves, J. H., Wang, Y., & Grove, N. P. (2019). The evaluation of a hybrid, general chemistry laboratory curriculum: Impact on students' cognitive, affective, and psychomotor learning. *Journal of Chemical Education, 96*(6), 1058-1067. doi:10.1021/acs.jchemed.8b00637

Fautch, J. M. (2015). The flipped classroom for teaching organic chemistry in small classes: is it effective? *Chemistry Education Research and Practice*, *16*(1), 179–186. https://doi.org/10.1039/c4rp00230j

Fitzgerald, N., & Li, L. (2015). Using presentation software to flip an undergraduate analytical chemistry course. *Journal of Chemical Education*, *92*(9), 1559–1563. https://doi.org/10.1021/ed500667c

Fung, F. (2017). Adopting lightboard for a chemistry flipped classroom to improve technology-enhanced videos for better learner engagement. *Journal Of Chemical Education*, *94*(7), 956-959. https://doi.org/10.1021/acs.jchemed.7b00004

Ginns, P., & Ellis, R. (2007). Quality in blended learning: Exploring the relationships between online and face-to-face teaching and learning. *The Internet and Higher Education*, *10*(1), 53–64. https://doi.org/10.1016/j.iheduc.2006.10.003

Graham, C. R. (2006). Blended learning systems: Definition, current trends, and future directions. In: C.J. Bonk & C.R. Graham (Eds.) *Handbook of Blended Learning: Global Perspectives, Local designs* (pp. 3-21). Pfeiffer Publishing: San Francisco

Graham, C. R., Woodfield, W., & Harrison, J. B. (2013). A framework for institutional adoption and implementation of blended learning in higher education. *The Internet and Higher Education*, *18*, 4–14. https://doi.org/10.1016/j.iheduc.2012.09.003

Halim, N. D. A. et al. (2017). The effects of cooperative learning activities in blossoms lesson towards students' achievement in learning chemistry. *Man in India*, *97*(19), 323–329.

Hanson, C. L., Ness, C. V., Gadbury-Amyot, C. C., & Crain, G. (2014). Development and outcomes of an online-onsite hybrid dental admissions enhancement pilot program. *Journal of Dental Education, 78*(10), 1451-1459. doi:10.1002/j.0022-0337.2014.78.10.tb05819.x

Hibbard, L. (2019). Case studies for general chemistry: Teaching with a newsworthy story. *Journal of Chemical Education, 96*(11), 2528-2531. doi:10.1021/acs.jchemed.9b00420

Holton, E. F., Coco, M. L., Lowe, J. L., & Dutsch, J. V. (2006). Blended delivery strategies for competency-based training. *Advances in Developing Human Resources*, *8*(2), 210–228. https://doi.org/10.1177/1523422305286153

Huertas, A., Vesga, G., Vergara, A., & Romero, M. (2015). Effect of a computational scaffolding in the development of secondary students' metacognitive skills. *International Journal of Technology Enhanced Learning*, *7*(2), 143-159. https://doi.org/10.1504/ijtel.2015.072030

Hwang, G.-J., Lai, C.-L., & Wang, S.-Y. (2015). Seamless flipped learning: a mobile technology-enhanced flipped classroom with effective learning strategies. *Journal of Computers in Education*, *2*(4), 449–473. https://doi.org/10.1007/s40692-015-0043-0

Jihad, T., Klementowicz, E., Gryczka, P., Sharrock, C., Maxfield, M., Lee, Y., & Montclare, J. K. (2018). Perspectives on blended learning through the online platform, lab Lessons, for chemistry. *Journal of Technology and Science Education, 8*(1), 34-44. doi:10.3926/jotse.312

Kaur, A., & Ahmed, A. (2006). E-learning challenges as perceived by communities of practice: Open University Malaysia's experiences. *Asian Association of Open Universities Journal*, *2*(1), 51–65. https://doi.org/10.1108/aaouj-02-01-2006-b006

Kaur, M. (2013). Blended learning - its challenges and future. *Procedia - Social and Behavioral Sciences*, *93*, 612–617. https://doi.org/10.1016/j.sbspro.2013.09.248

Kennepohl, D. K. (2013). Learning from blended chemistry laboratories. *In Proceedings of the 2013 IEEE Fifth International Conference on Technology for Education (t4e 2013),* IEEE Computer Society, December 18-20, 2013,Kharagpur, India.

Krasulia, A. (2015). Blended learning: Advantages and disadvantages in the classroom. Retrieved from https://essuir.sumdu.edu.ua/handle/123456789/67256

Kumar, R., & Pande, N. (2017). Technology-mediated learning paradigm and the blended learning ecosystem: What works for working professionals? *Procedia Computer Science*, *122*, 1114–1123. https://doi.org/10.1016/j.procs.2017.11.481

Lee, T. T., Sharif, A. M., & Rahim, N. A. (2018). Designing e-content for teaching basic chemistry concepts in higher education: A needs analysis. *Journal of Turkish Science Education*, *15*(4), 65–78. https://doi.org/10.12973/tused.10246a)

Legron-Rodriguez, T. (2019). Generative learning strategies and pre-lecture assignments in a flipped forensic chemistry classroom. *ACS Symposium Series*, *1324*, 233–241. https://doi.org/10.1021/bk-2019-1324.ch013

Lewis, S. E. (2018). Goal orientations of general chemistry students via the achievement goal framework. *Chemistry Education Research and Practice*, *19*(1), 199–212. https://doi.org/10.1039/c7rp00148g

Lenczewski, M. S. (2016). Scaffolded semi-flipped general chemistry designed to support rural students' learning. *Journal of Chemical Education*, *93*(12), 1999–2003. https://doi.org/10.1021/acs.jchemed.6b00320

Liu, Y., Raker, J. R., & Lewis, J. E. (2018). Evaluating student motivation in organic chemistry courses: Moving from a lecture-based to a flipped approach with peer-led team learning. *Chemistry Education Research and Practice*, *19*(1), 251–264. https://doi.org/10.1039/c7rp00153c

Liu, Z., Lin, Y., & Zhong, Z. (2019). Preliminary evaluation of a reform of methods to teach pharmaceutical polymer materials science to a class of diverse majors. *Indian Journal of Pharmaceutical Education and Research*, *53*(4), 613–619. https://doi.org/10.5530/ijper.53.4.122

Lo, C., & Tang, K. (2018). Blended learning with multimedia e-learning in organic chemistry course. *In Proceedings of the 2018 International Symposium on Educational Technology (ISET),* Kansai University, July 31 - August 2, 2018, Osaka, Japan.

Mcdowell, T. R., Schmittzehe, E. T., Duerden, A. J., Cernusca, D., Collier, H., & Woelk, K. (2019). A student-choice model to address diverse needs and promote active learning. *Journal of Science Education and Technology, 28*(4), 321-328. doi:10.1007/s10956-019-9768-2

Mooring, S. R., Mitchell, C. E., & Burrows, N. L. (2016). Evaluation of a flipped, large-enrollment organic chemistry course on student attitude and achievement. *Journal of Chemical Education*, *93*(12), 1972–1983. https://doi.org/10.1021/acs.jchemed.6b00367

Nugraheni, A.R.E., Adita, A., & Srisawasdi, N. (2020). Blended learning supported chemistry course: A systematic review from 2010 to 2019. *In Proceedings of the 28th International Conference on Computers in Education (ICCE2020),* Asia-Pacific Society for Computers in Education, November 23-27, 2020.

Olakanmi, E. E. (2016). The effects of a flipped classroom model of instruction on students' performance and attitudes towards chemistry. *Journal of Science Education and Technology, 26*(1), 127-137. doi:10.1007/s10956-016-9657-x

Owston, R., York, D. N., & Malhotra, T. (2019). Blended learning in large enrolment courses: Student perceptions across four different instructional models. *Australasian Journal of Educational Technology*. https://doi.org/10.14742/ajet.4310

Ozdilek, Z. (2013). Pre-service science teachers' perceptions about effective design of blended university chemistry courses. *Turkish Online Journal of Distance Education*, *14*(3), 165–180. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84884154183&partnerID=40&md5=e527a292873a0ece9a8f9b46ec2cf6aa

Park, Y., Yu, J. H., & Jo, I.-H. (2016). Clustering blended learning courses by online behavior data: A case study in a Korean higher education institute. *The Internet and Higher Education*, *29*, 1–11. https://doi.org/10.1016/j.iheduc.2015.11.001

Parsons, A. F. (2019). Flipping introductory retrosynthetic analysis: An exemplar course to get the ball rolling. *Journal of Chemical Education*, *96*(4), 819–822. https://doi.org/10.1021/acs.jchemed.8b00946

Pilcher, S. C. (2017). Hybrid course design: A different type of polymer blend. *Journal of Chemical Education*, *94*(11), 1696–1701. https://doi.org/10.1021/acs.jchemed.6b00809

Pima, J. M., Odetayo, M., Iqbal, R., & Sedoyeka, E. (2018). A thematic review of blended learning in higher education. *International Journal of Mobile and Blended Learning*, *10*(1), 1–11. https://doi.org/10.4018/ijmbl.2018010101

Ping, G. L. Y., Lok, C., Wei Yeat, T., Cherynn, T. J. Y., & Tan, E. S. Q. (2018). "Are chemistry educational apps useful?" – a quantitative study with three in-house apps. *Chemistry Education Research and Practice*, *19*(1), 15–23. https://doi.org/10.1039/c7rp00094d

Polizzi, N. F., & Beratan, D. N. (2015). Open-access, interactive explorations for teaching and learning quantum dynamics. *Journal of Chemical Education*, *92*(12), 2161–2164. https://doi.org/10.1021/acs.jchemed.5b00662

Premthaisong, S., Chaipidech, P., Panjaburee, P., Chaijaroen, S., Srisawasdi, N. (2020). Mobile technology facilitated chemistry learning in school: A systematic review from 2010 to 2019. In J. Shen., Y. Chang., Y. Su., & H. Ogata (Eds.) *Cognitive Cities* (pp. 652-662).

Rau, M. A., Kennedy, K., Oxtoby, L., Bollom, M., & Moore, J. W. (2017). Unpacking "active learning": A combination of flipped classroom and collaboration support is more effective but collaboration support alone is not. *Journal of Chemical Education*, *94*(10), 1406–1414. https://doi.org/10.1021/acs.jchemed.7b00240

Reay, J. (2001). Blended learning-a fusion for the future. *Knowledge Management Review, 4*(3), 6.

Ring, J. (2017). Confchem conference on select 2016 BCCE presentations: Specifications grading in the flipped organic classroom. *Journal of Chemical Education*, *94*(12), 2005–2006. https://doi.org/10.1021/acs.jchemed.6b01000

Robert, J., Lewis, S. E., Oueini, R., & Mapugay, A. (2016). Coordinated implementation and evaluation of flipped classes and peer-led team learning in general chemistry. *Journal of Chemical Education*, *93*(12), 1993–1998. https://doi.org/10.1021/acs.jchemed.6b00395

Rooney, J. E. (2003). Blended learning opportunities to enhance educational programming and meetings. *Association Management, 55*(5), 26-32.

Ryan, M. D., & Reid, S. A. (2015). Impact of the flipped classroom on student performance and retention: A parallel controlled study in general chemistry. *Journal of Chemical Education*, *93*(1), 13–23. https://doi.org/10.1021/acs.jchemed.5b00717

Sands, P. (2002). Inside outside, upside downside: Strategies for connecting online and face-to-face instruction in hybrid courses. *Teaching with Technology Today, 8*(6).

Schultz, D., Duffield, S., Rasmussen, S. C., & Wageman, J. (2014). Effects of the flipped classroom model on student performance for advanced placement high school chemistry students. *Journal of Chemical Education*, *91*(9), 1334–1339. https://doi.org/10.1021/ed400868x

Seery, M. K. (2015). Confchem conference on flipped classroom: Student engagement with flipped chemistry lectures. *Journal of Chemical Education*, *92*(9), 1566–1567. https://doi.org/10.1021/ed500919u

Seraji, F., Attaran, M., & Azizi, S. M. (2019). Blended learning researches in Iran: Several fundamental criticisms. *Digital Education Review*, *36*, 190–206. https://doi.org/10.1344/der.2019.36.190-206

Shattuck, J. C. (2016). A parallel controlled study of the effectiveness of a partially flipped organic chemistry course on student performance, perceptions, and course completion. *Journal of Chemical Education, 93*(12), 1984-1992. doi:10.1021/acs.jchemed.6b00393

Shen, Q. (2016). Blended learning activities in a chemistry experiment. *World Transactions on Engineering and Technology Education*, *14*(1), 70–76.

Staker, H., & Horn, M. B. (2012). *Classifying k-12 blended learning*. Innosight Institute.

Stewart, J. J., & Dake, G. R. (2019). Activating students' prior knowledge using a bridge activity as an initial interactive discussion in a flipped organic chemistry course. *Journal of Chemical Education, 96*(11), 2426-2431. doi:10.1021/acs.jchemed.9b00370

Thomas, A. L. P. (2017). Confchem conference on select 2016 BCCE presentations: Putting your own personal twist on a flipped organic classroom and selling the idea to students. *Journal of Chemical Education*, *94*(12), 2013–2015. https://doi.org/10.1021/acs.jchemed.6b00993

Thorne, K. (2004). *Blended learning: How to integrate online and traditional learning*. Kogan Page: London.

Tsoi, M. (2010). Supporting productive integration of web 2.0-mediated collaboration. *IFIP Advances In Information And Communication Technology*, *324*, 401-411.

Visentin, S., Ermondi, G., Vallaro, M., Scallet, G., & Caron, G. (2013). Blended learning for courses in pharmaceutical analysis.part 2. *Journal of E-Learning and Knowledge Society, 9*(1), 93-102.

Ward, J., & La Branche, G. A. (2003). Blended learning: The convergence of e-learning and meetings. *Franchising World, 35*(4), 22-23.

Watson, J. (2008, March 31). Blended learning: The convergence of online and face-to-face education. Promising practices in online learning. Retrieved January 20, 2020, from https://eric.ed.gov/?id=ED509636

Weaver, G. C., & Sturtevant, H. G. (2015). Design, implementation, and evaluation of a flipped format general chemistry course. *Journal of Chemical Education, 92*(9), 1437-1448. doi:10.1021/acs.jchemed.5b00316

Young, J. R. (2002). "Hybrid" teaching seeks to end the divide between traditional and online instruction. *Chronicle of Higher Education, 48*(28), A33.

Zeng, X., Yu, C., Liu, Y., Hu, X., Hao, Q., Jiang, Y., Dai, W., Zhang, K., & Teng, B. (2018). The construction and online/offline blended learning of small private online courses of principles of chemical engineering. *Computer Applications in Engineering Education*, *26*(5), 1519–1526. https://doi.org/10.1002/cae.22044